UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 906

Contribution from the Bureau of Public Roads
THOMAS H. MACDONALD, Chief

Washington, D. C. March 23, 1921

THE USE OF CONCRETE PIPE IN IRRIGATION

By

F. W. STANLEY, Senior Irrigation Engineer, with Introductory Paragraphs by SAMUEL FORTIER, Chief of Irrigation Division

CONTENTS

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CONTENTS.

INTRODUCTION.

In the more arid parts of the West, arable land possesses little value without water. The water which can be put to a beneficial use is limited to relatively small quantities, so that when it is fully utilized, only a small percentage of the total fertile and arable lands of the West can be reclaimed by irrigation. In recent years, owing to the rapid increase in the value of soil products, intensively farmed land under irrigation systems has risen in many cases to double its former, prewar value. This great advance in the value of irrigated land has placed a premium on water, and a widespread effort is being made to convey, distribute, and use the appropriated waters in such a way as to incur the least possible loss. Every gallon of water wasted by seepage and absorption in porous earthen channels or in careless use on the land, robs the farmer of so much profit, whereas every gallon saved protects fertile soil from water-logging, and results in larger yields and profits to the grower.

An experience covering a period of over a quarter of a century on the Pacific Coast, and more especially in California, has demonstrated that large quantities of water can be saved by the substitution of pipe for earthen ditches. The results of a large number of measurements made by the irrigation division of this bureau show that the transmission losses in earthen channels vary from 10 to 60 per cent, and average fully 35 per cent of the quantity of water admitted through the intake. When pipes are substituted for earthen channels, the loss of water in conveyance is usually negligible.

The use of pipe for the carriage of water and of pipe systems for its distribution to farmers, not only prevents loss of water but affords better facilities for its control, distribution, and delivery. Irrigating land by means of open channels in earth is a laborious and unpleasant task, wasteful of water, time, and effort. On the contrary it can be rendered comparatively easy and pleasant if the proper equipment is provided in the way of pipe, pipe systems with proper gates, turnouts, and other fixtures. The interest on the cost of such betterments for highly profitable crops is more than likely to be amply compensated for by the water and labor saved and a more uniform moistening of the soil.

The purpose of this bulletin is to present to the irrigation farmers and orchardists of the West information concerning pipe and pipe systems and more especially the use of concrete pipe in irrigation, with such practical suggestions regarding making and laying as may enable those engaged in this work to avoid mistakes and attain satisfactory results.

THE USE OF PIPE IN IRRIGATION.

Before proceeding to a discussion of concrete pipe as used in irrigation systems, brief references are made herewith to other kinds of piping used for the same purpose. These other kinds include metal pipe, wood pipe, and vitrified clay pipe. These, with concrete pipe, differ in strength, durability, cost, and general fitness for any particular location and use, and in planning an irrigation system where pipes are to be used in quantity, care should be exercised to select the kind of piping that will best meet the requirements of each individual case. It happens quite frequently that the same kind of piping can not be advantageously used to convey water to all parts of an irrigation enterprise.

Metal pipes, and especially riveted steel pipes, possess strength in a high degree and on this account should be used for high pressures and where excessive fluctuations in pressure occur due to water-hammer and other causes. On the other hand riveted steel pipe of the quality now manufactured is not durable when exposed to un-

favorable conditions unless protected by an asphaltic or other similar coating or galvanized. The dipping of sections of riveted pipe in a bath of hot asphalt has long been practiced, but if the coating becomes brittle when cooled, it is liable to chip off and expose the metal. To guard against abrasions in the coating, roofing paper cemented to the pipe with hot tar has been successfully used on several large systems, notably those of the Terra Bella irrigation district in Tulare County and the Sweetwater Water Co. of San Diego County, Calif. In wrapping pipe, a roll of roofing paper is cut in a number of strips by means of a homemade machine. This machine winds a roll of roofing paper from one spindle to another, meanwhile drawing the paper over a series of knives; the knives can be regulated so as to cut any width of strip desired. The pipe to be wrapped is placed on a spindle which is suspended over a trough. It is then revolved by a crank by one man, while another guides the strip of roofing paper. The paper is thus wound spirally the length of the pipe. A third man pours hot tar between the roofing paper and the pipe while the winding process is going on.

For medium water pressures created by heads of 20 to 100 feet and over, wood pipe may be used. The kind of wood pipe known as continuous stave pipe may be built in sizes ranging from 1 to 15 feet in diameter. The materials of which this pipe is composed consist of wood staves, steel bands, and cast-iron clips, which are shipped to the site usually direct from the manufacturer, and the pipe is laid continuously either in a trench or on the surface of the ground along the line of the location.

So-called machine-banded wood pipe is made in the factory in shipping lengths and in sizes ranging from 2 to 52 inches. In making this pipe the staves are held together by galvanized steel wire, wound spirally and spaced according to the pressure to be sustained. After the pipe is banded and the ends are milled for couplings, each shipping length is dipped in a bath of hot asphalt and when withdrawn is rolled in sawdust or shavings. The light weight and cheapness of wood pipe and the ease with which it can be shipped and transported over mountainous and out-of-the-way places are marketable advantages. The chief objection to the use of wood pipe is the tendency of the wood to decay when in contact with the earth, exposed to the air, and alternately wet and dry. When wood pipe is kept continuously under water pressure, or covered to a depth of 2 feet or more in tight soil, it has been known to give excellent service for 30 years.

Vitrified clay pipe when well made is a suitable pipe for irrigation purposes, providing the head does not exceed 15 feet. It is easy to lay, has a smooth interior surface, and in consequence a fairly low friction factor. It is not as a rule injuriously affected by alkali. Most

of the failures arising from the use of this kind of piping in the West have been due to the practice of laying discarded sewer pipe as distributaries in irrigation systems. Some of these are imperfectly burned and glazed, possess little strength and are apt to disintegrate. Others are cracked, permitting roots to enter the pipe and obstruct the passageway as well as break up the pipe. The cost of a good quality of clay pipe is higher than a corresponding quality of plain concrete pipe. The latter will also safely withstand higher internal pressures. For these and other reasons clay pipe has not been extensively used for irrigation purposes throughout the Western States.

INCASING OLD PIPE OF METAL AND WOOD WITH CONCRETE.

Old pipe of metal and wood may be converted into concrete pipe by placing a layer of concrete around their exteriors. This can often be done with the pipe in place, under pressure and in use, providing the leaks are not too troublesome.

In the case of steel pipe, the pipe is uncovered and scraped clean of dirt and rust with steel brushes. The excavation is made large enough to permit forms to be placed around the sides and part of the bottom of the pipe. Before placing the forms triangular mesh reinforcing wire of the right width is wound spirally around the pipe and is kept away from the pipe by small concrete briquettes. Wooden forms 12 feet in length are then put in place, allowing sufficient space between the forms and the exterior of the pipe for the proper thickness of concrete shell. Concrete is then poured within the form, which is allowed to remain in place 24 hours before removing. Recently the Sweetwater Water Co. of San Diego County, Calif., incased 3,125 feet of 8-inch steel-riveted pipe for a total cost of $1.13 per foot, which included trenching, backfilling, forms, etc. The same company also encased 600 feet of 12-inch pipe for $1.39 per foot. Several years ago the Temescal Water Co., of Corona, Calif., incased with concrete 10,000 feet of riveted steel pipe, under a maximum head of 80 feet, which had been in service for 30 years,[1] also shorter lengths of pipes 30 and 18 inches in diameter. The cost inclusive of trenching, forms, backfilling, etc., was $2.50 per foot for the 30-inch pipe, $1.70 for the 24-inch, and $1.40 per foot for the 18-inch pipe. The price of labor at that time was $2.25 to $2.50 per day, while cement was worth $2.30 per barrel. The form used is shown in figure 1.

CONCRETE PIPE.

During the past 10 or 15 years the greater part of the pipe used for irrigation pipe systems has been made of concrete. The prin-

[1] See article in Engineering News-Record by H. R. Case, Sept. 20, 1917.

cipal reasons for its extended use are its relative cheapness, durability, strength, and general adaptability to irrigation requirements. An excellent quality of cement is made in scores of factories in the West and sold at relatively low prices, while the other ingredients of sand, gravel, rock-dust, and broken rock usually are found in close proximity to where the pipe is made.

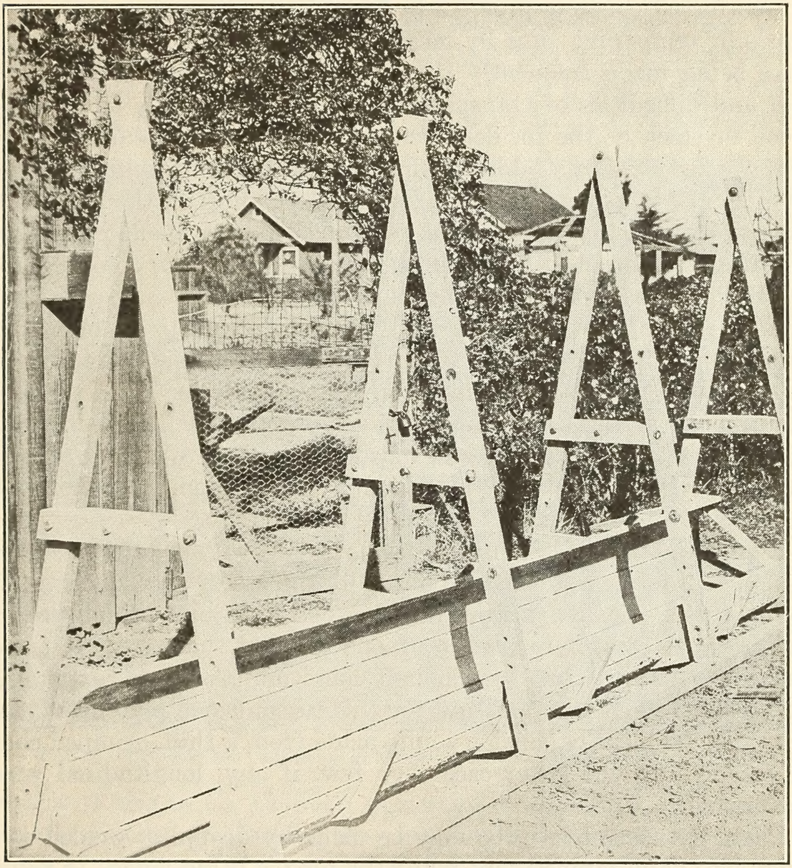

Fig. 1.—Form used in incasing riveted steel pipe with concrete.

Concrete pipe is made both reinforced and plain, the former having more or less steel embedded in the concrete shell in order to increase its tensile strength. A few years ago plain concrete pipe was placed in the same class as vitrified clay pipe as regards tensile strength and limited to less than 15 feet head. This precaution was then necessary owing to the inferior quality of the pipe made, and failures were common even under less than 10-foot heads. In recent years a marked improvement has been produced by substituting a proper concrete mixture for the cement and sand formerly used and

by adopting better methods of molding, tamping, curing, and laying. There is to-day in successful operation a large mileage of unreinforced pipe from 6 to 24 inches in diameter under heads of 25 to 40 feet, while other lines are under heads of 40 to 100 feet. One pipe line 16 inches in diameter is successfully operating under a head of 80 feet.

REINFORCED CONCRETE PIPE.

Reinforced concrete pipe, 12 to 72 inches in diameter, is made in yards or temporary sites by means of collapsible forms, the larger sizes being made frequently near the point of laying to lessen the cost and difficulties of transportation. The forms may be of either wood or steel, or the inside form of steel and the outside of wood. Either wire mesh or steel hoops may be used for reinforcing material, the size and spacing of the reinforcing depending on the head to be exerted against the pipe. Most reinforced pipe is made by placing a cage of reinforcing wire mesh between the inside and outside forms and then pouring in a wet mixture of concrete. The concrete is tamped into place. The molds are removed in about 24 hours, the pipe being kept moistened while curing. Most manufacturers of reinforced pipe aim to use enough steel to take all tension in the pipe, the concrete acting as an impervious shell only. It has been found that poured concrete has a lower tensile strength than a drier mixture that is well tamped, but it is difficult to tamp pipe well when wire mesh reinforcing is used.

Reinforced pipe is laid in a trench as is done with ordinary concrete pipe. The joints are usually poured by the use of special forms for the purpose. Some firms put out a special lock joint, which ties the longitudinal reinforcing wires of one joint to the next. It is not usual however, to provide enough longitudinal wires to take all stresses due to contraction, and for this reason some pipe firms have provided frequent expansion joints made from a thin, crimped sheet of copper. In the latter case very few, if any, longitudinal wires are needed.

Partially reinforced pipe may be made by dropping welded wire rings into hand-tamped pipe while the pipe is being made. Enough rings may be inserted to take all the tension, or two or three rings may be used in every length, which are expected to prevent a crack from one pipe being transmitted to another.

There are several methods of constructing continuous reinforced pipe one of which is shown in figure 2. This is usually done by using a collapsible inner form which is moved along the trench as the pipe is being made. An outside form may be used on the sides and top, or the trench may be cut so as to act as the outside form.

The Whittier Water Co., of Whittier, Calif., has laid considerable quantities of continuous reinforced concrete pipe. One installation

is rectangular in cross section, 36 inches by 36 inches inside dimensions. Collapsible wooden forms were used, 12 feet in length, with triangular reinforcing wire mesh placed in two sections. One section of wire mesh is laid on top of the forms, with the edges turned down into the side walls, and the other section covers the bottom and extends up the sides. The sides of the earthen excavation were cut so as to leave a thickness of concrete of 6 inches. This conduit is made to stand 50 feet head. The total cost was about $2.40 per foot.

If continuous pipe is laid in cool weather and is not allowed to dry before being filled with water, there may be no trouble with contraction cracks, but this class of pipe would probably give considerable

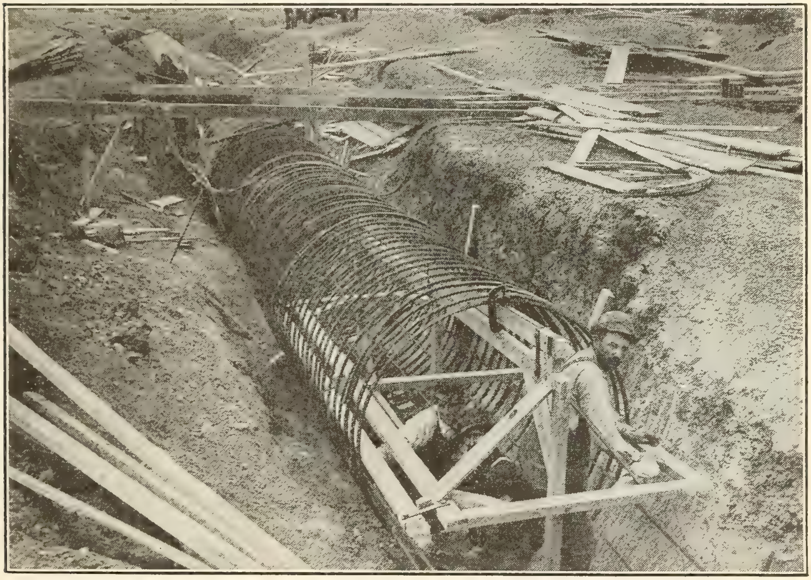

Fig. 2.—Showing one method of building continuous reinforced-concrete pipe.

trouble if laid in the summer, especially if allowed to dry out during the winter. If possible, the pipe should be covered with at least 2 feet of earth, and if the soil is kept moist curing should take place without the concrete cracking.

One firm in Los Angeles has given the following prices at the yard, Los Angeles, under date of May, 1919, for reinforced concrete pipe:

Diameter.	Price per foot.	Diameter.	Price per foot.
12 inches	$0.86	36 inches	$3.30
16 inches	1.13	48 inches	5.15
18 inches	1.24	60 inches	7.40
20 inches	1.37	72 inches	10.12
24 inches	1.70		

The cost of laying is estimated at about 1 cent per foot for each inch of diameter of pipe, but conditions may arise where it may be much more, especially if siphons are installed.

MANUFACTURE OF PLAIN CONCRETE PIPE.

Plain concrete pipe may be divided into two general classes—hand-tamped and machine-made pipe. Hand-tamped pipe is made by tamping concrete between inside and outside collapsible forms. The forms usually run from 6 inches to 36 inches inside diameter. The pipe is made for the most part in 2-foot lengths, although some is made 30 inches in length. In making hand-tamped pipe, the forms are set up vertically on the ground or on a platform. Concrete is then poured between the forms by one man while another tamps. When the pipe is finished it is reamed off on top with a special reamer. The inside form is first removed by collapsing it and the pipe carried to the proper place in the yard, where the outside form is removed and the pipe allowed to set. Pipe should always be kept thoroughly moist for at least 10 days before it is cured. If the concrete is moist enough when the pipe is tamped the outside form may be stripped, i. e., pulled off vertically, without loosening the jacket. If so-called dry pipe is made, the forms can not be stripped, but the outside form must be loosened before lifting it off. The tongue and groove ends of the pipe are made to assist in laying. The groove end, which is usually a simple inside taper on the bottom of the pipe, is made by dropping a cast-iron ring between the forms. This ring is beveled to conform to the groove of the pipe, and is allowed to remain on the bottom of the pipe until the concrete has set sufficiently to move the pipe. (Fig. 3.) The tongue end of the pipe is made when the pipe is finished, and is accomplished by whirling the reamer over the top before the forms are removed. Some hand-tamped pipe is made with bell and spigot ends similar to the ordinary clay sewer pipe. When pipe is made in this way, the outside form is split so that the forms can be removed laterally.

Pipe machines[2] are roughly classified as tamping machines and troweling machines. Some tamping machines tamp the pipe very similarly to the hand-tamping process. The mechanism of most of these machines causes the pipe to revolve under the tamper while the concrete is poured in between the forms. A pneumatic air tamper may be used to tamp the pipe. The apparatus operating the air tamper is suspended over the forms, the air tamper being guided around the shell of the pipe by one man, while another feeds the concrete. The pneumatic hammer delivers about 700 blows a minute

[2] Arizona State Experiment Station Bulletin No. 86, by G. E. P. Smith.

under heavy pressure. In other respects the pipe is made as described under hand-tamped methods.

Troweling machines make use of iron vanes that force the concrete down and against the outside form. The vane or packerhead apparatus is revolved by machinery and at the same time is lifted from bottom to top of a length of pipe while it is being made. There are a number of different types of this class of machine, many of which make pipe very rapidly. The troweling process usually makes a pipe of smooth interior finish.

FIG. 3.—Concrete-pipe yard showing forms and cast-iron rings.

It is probable that other types of concrete pipe machines will come into the market in the near future. A machine that both tamps and trowels pipe is used now. Another machine has been recently invented that compresses the concrete in the molds by squeezing in the outside form. Many other possibilities are talked of which may soon become realities.

QUALITY OF CONCRETE PIPE.

Both hand-tamped and machine-made concrete pipes are often of very inferior quality, but it is encouraging to know that the quality is constantly improving. Most pipe makers will agree to deliver a high-grade pipe if the purchaser is willing to pay for it, but as long as the latter insists on getting the cheapest pipe he is apt to get the poorest quality. Some reputable firms, however, will not make an inferior grade and do not try to compete with pipe makers who sell

pipe that is made of poor materials, poorly tamped, or that lacks the proper proportion or kind of ingredients.

It is sometimes difficult to judge the quality of concrete pipe without having the necessary apparatus for testing it. Usually, however, an intelligent examination with the application of a few simple tests, will give a fair indication of its worth. Two requirements are necessary for the best grades—strength and imperviousness. Pipe may stand high pressures and still be rather porous, but a dense pipe that is nearly impervious can be made if proper precautions are taken in the choice of materials and the mixing and tamping or troweling of the concrete.

Porosity can be tested by filling a length of pipe with water after one end has been plugged. If the outside of the pipe remains dry after water has been in the pipe for several hours, it is probable that the pipe will show very little seepage when under pressure, as seepage through the shell of a concrete pipe usually shows up under low pressure and does not increase proportionately with increasing pressures. The porosity of pipe can be estimated by weighing a small piece of concrete pipe before and after soaking in water. Dense pipe should increase very little in weight after being soaked for 10 minutes.

Hand-tamped pipe is often made with concrete that is far too dry, for the reason that a dry mixture is easier to handle when made by hand and will stand up with less tamping than a wet mixture. Some of the dry mixed, poorly tamped pipe will absorb water rapidly and become saturated throughout in a few minutes when soaked in water. A wet mixture is usually quite impervious, as it must be tamped well in order that the forms may be easily removed. Pipe that is made from a wet mixture of concrete will show a fine webbing on the outside of the pipe, while the wettest will show streaks and coarse webbing. This webbing or streaking shows up plainly after the pipe is cured. Such markings are due to moisture being forced outward against the outside form when the pipe is tamped. This mixture of water and cement is streaked vertically along the outside of the pipe when the form is stripped from the newly made pipe.

Wet-mixed pipe may not have the maximum strength, but usually it can be depended upon for high-pressure work, and it should be durable and impervious if well cured in the yard. Pipe that is made with the best known proportion of water in the mixture, it being not too dry and at the same time wet enough, will show a fine webbing on the outside of the pipe, and will also be hard and tough, providing always that the materials are of good quality and well tamped, or compressed, and cured. Wet-mixed pipe will usually slump when the forms are removed, which may cause a lopsided or

distorted pipe. Such pipe is more difficult to lay, but if care is taken in laying it should be satisfactory. Some of the pipe that presents the most attractive appearance in the yard may be of poor quality on account of having been mixed too dry.

The best grade of pipe for use against pressure should withstand a heavy blow with a hammer and should give a clear, ringing sound. The pipe should be dense when broken and be difficult to scratch with a knife. The best pipe can be thrown from a wagon to the ground without breaking, although this is not recommended except for a test.

The best grades must also be made from materials that will pass the test for any good concrete work. As much hard, broken rock or gravel containing a high proportion of hard pebbles should be used as can be incorporated. High-pressure pipe often contains as much as 50 per cent rock and is made with 1 part of cement to 3 parts of aggregate. Pipe for use under low pressures is often made of 1 part of cement to 5 parts of sand and rock. Some machines will not handle a large proportion of rock and with such more cement must be used to get the same grade of pipe. Machines are usually more reliable for compressing the concrete, and the product is liable to be more uniform. At the same time some of the most reliable pipe-making firms in the West are using hand-tamped methods, and guaranteeing their product.

Some farmers buy equipment for making hand-tamped pipe and make their own pipe. This practice is not to be encouraged as a rule, as experience is necessary if a reliable product is to be turned out. The saving in cost is small in many cases, and failures may make this method an expensive experiment. The safest thing for a farmer to do is to buy pipe from a reliable firm, have the same firm lay the pipe, and demand a guaranty that the pipe will conform to the specifications.

It is not intended to discuss the best materials required for making concrete pipe, as this subject will be taken up in another bulletin. Briefly stated, however, the sand should be clean, the rock clean, hard, and durable, and the whole aggregate well graded. If gravel is used, the materials should be clean and hard, with a minimum amount of organic matter. The presence of clay or silt free from organic matter in the gravel may not be harmful, and tends to make an impervious pipe if it is not present in too large quantities. Rock dust may be added with benefit to the pipe, while a certain proportion of lime will tend to make an impervious pipe. Soft or partially disintegrated rock or gravel is very harmful, especially if high-pressure pipe is desired. When possible, materials should be tested in the laboratory or test lengths of pipe made, which can be tested to fail-

ure in the yard. There are several types of apparatus designed by engineers of this bureau which can be used by pipe manufacturers for such purposes. In fact all pipe yards should be equipped with testing apparatus that can test pipe for an installation. A farmer should demand tests on pipe that he is ordering especially for high-pressure lines.

As regards durability, concrete pipe, if well made and laid, should last for generations. It is the improperly made pipe which causes failures and early renewal. The experience of southern California shows that the good concrete pipe installed 30 years ago is still in excellent condition, whereas some of the inferior pipe has been renewed in less than 5 years after laying.

COST OF UNREINFORCED CONCRETE PIPE.

The price of concrete pipe has increased somewhat during the last two or three years, but the increase has been less than in other types of pipe. The following prices were quoted in July, 1919, by a number of the larger manufacturers in southern California.

Inside diameter of pipe.	Price per foot at yard.	Price per foot laid in light soil.	Price per foot laid in heavy soil.	Inside diameter of pipe.	Price per foot at yard.	Price per foot laid in light soil.	Price per foot laid in heavy soil.
6 inches	$0.12½	$0.25	$0.28	18 inches	$0.46	$0.65	$0.85
8 inches	.14	.27	.30	20 inches	.70	1.00	.150
10 inches	.16	.30	.34	24 inches	.90		
12 inches	.20	.34	.38	30 inches	1.60		
14 inches	.25	.40	.44	36 inches	2.00		
16 inches	.35	.52	.60				

NOTE.—Prices laid, include trenching and backfilling.

Prices quoted at the yard by the Concrete Pipe Manufacturers' Association of Northern and Central California July, 1919, are as follows:

Inside diameter of pipe.	Price per foot.	Inside diameter of pipe.	Price per foot.
6 inches	$0.20	18 inches	$0.72
8 inches	.22	20 inches	.85
10 inches	.28	24 inches	1.20
12 inches	.35	30 inches	1.90
14 inches	.46	36 inches	2.50
16 inches	.70		

Some firms quote prices for pipe that will stand extra pressure, and guarantee the product. The cost of this pipe is about 30 per cent higher than stock pipe for 40-foot heads, and about 50 per cent higher for 50-foot heads. One firm makes pressure pipe of standard thickness from 6 to 12 inches in diameter that will stand 70 to 80 feet head, and sells it at a price 25 to 40 per cent higher than the ordinary low-

pressure pipe. Pipes of 8 to 12 inches in diameter are made in stock of double thickness, which will stand heads of 150 feet and over, but the prices are about three times as high as stock pipe. Stock pipe should be safe under pressures of from 20 to 35 feet.

In connection with the above-quoted prices, it may be stated that many pipe manufacturers who operate small plants sell pipe much cheaper than the figures given.

LAYING CONCRETE PIPE.

Concrete pipe should be laid deep enough in the trench so as to reduce the range of temperature and to be safe from injury against plows, subsoilers or other farm implements. There should be at least 12 inches of earth over the top of all kinds of pipe, and high pressure pipe should have a top covering of at least 18 inches. Temperature changes in the shell of the pipe are greatly reduced when the pipe is buried deeply, and less trouble is experienced from expansion and contraction. The moisture content within the shell of the pipe is likewise kept more uniform than where the upper half is laid near the surface of the ground.

The trench should be wide enough to allow room for a man's feet when he is straddling the pipe in the act of laying the pipe. It is a mistake to make the trench too narrow, especially when large-sized pipe is laid, as there must be room to finish off the joints. Excavation in soil that is not too hard or rocky may be done with a plow and V scraper. Road scrapers and ditchers are sometimes used to start large excavations, but trenches so made are too wide as a rule. There are several makes of tile trenching machines that are used for large installations, and where there are no obstructions to interfere with the machine it may pay to use one. These may be operated over the same trench twice, thus making it of nearly double width. For the most part trenching is done with pick and shovel—handwork being necessary where pipe is laid among full-grown trees in an orchard.

Some contractors lay pipe by force account, charging a commission of 10 to 15 per cent for tools and supervision, for the reason that it is difficult to make an estimate of the cost of excavation, as trenching in hardpan, adobe, or soil full of boulders may cost several times as much as a trench in loose loam or sand. Some trenching in favorable soil has been done for 3 to 7 cents per foot for 12-inch pipe, while the actual cost of a trench for 24-inch pipe near Azusa, Calif., where bowlders were encountered, was about 35 cents per foot. Trenching for 12-inch pipe in adobe soil near Santa Ana, Calif., with a trenching machine was done for 5 cents per foot. Handwork for heavy soil often costs 15 to 20 cents per foot for 12-inch pipe.

The bottom of the trench should be laid as nearly as possible to grade, but the grade does not need to be uniform where the pipe is under pressure, although sudden changes in grade should be avoided, as such irregularities in the pipe line may collect air, which will decrease the carrying capacity of the pipe. If it is not possible to avoid alternate dips and rises, air vents should be provided for at the highest points in the line. Where the line makes a deep dip, a blow-off valve should be installed at the lowest point, so that any accumulation of sand or trash can be blown out.

Most experienced pipe layers lay small sizes of pipe by standing the joint to be laid on end and filling the groove end with mortar. The pipe is then firmly pressed against the tongue end of the pipe that is already laid in the ground, care being taken to get a good bond of mortar between the ends of the pipe. The mortar is smoothed off with a trowel on the outside, and the inside brushed smooth with a long-handled brush. The ends of the pipe are always wetted with a brush before applying the mortar.

Large-diameter pipe is usually laid by placing a batch of mortar in the bottom of the groove of the pipe that is laid and on top of the tongue end of the pipe to be laid. The tongue and groove of the two joints of pipe, respectively, are then pressed together and the joints filled in by hand, using a rubber glove or part of an automobile inner tube over the hand to protect it from the action of the cement. The inside of pipe of a diameter less than 22 inches is finished off by a long-handled brush, but larger pipe is finished or pointed off by a man who works inside of the pipe. If it is possible for a man to work inside the pipe it is best to finish the inside of the joints 24 hours or longer after the pipe has been laid. This gives the pipe time to settle, otherwise joints may crack if finished off at once. The pipe also has time to expand or contract before the inside is finished. For this reason most contractors would rather guarantee pipe against leaks when it is large enough to permit a man to work within it.

Pressure pipe and the larger sizes of ordinary pipe are usually finished with banded joints, but small pipe that is to be under low pressure is not banded as a rule. The band is formed around the joint on the outside of the pipe with a trowel. The average size of band is about one-half to three-fourths inch thick over the joint and 4 to 6 inches wide. Some pipe layers reinforce the joint of high pressure with wire mesh. The wire is tied around the joint and the band made by plastering the mortar over it.

Laying cores are made use of occasionally in assisting to make joints. The core fits inside the pipe and prevents mortar from being projected into it.

Mortar used in laying is usually made of one part of cement to one and one-half parts of fine sand. The mortar is often made by

mixing the sand and cement with lime water. The addition of slaked lime makes the mortar easier to handle. One man who has had considerable experience with large sizes of pipe will not use lime in the mortar in sizes over 20 inches, as he claims mortar mixed with lime will tend to crack in the larger sizes.

Back filling should follow immediately after laying. If the earth used for back filling is moist, the mortar in the joints will cure better. Pipe laid in the trench is usually dry and a moist earth used for back filling will tend to moisten the pipe and cause a slight expansion. If the expansion takes place before the mortar in the joints is set, the pipe will conform to the new condition created by squeezing the mortar more compactly at the joints, instead of shoving the pipe ahead, which may cause failure at curves or destroy diversion boxes by crushing. The temperature in the trench after back filling is usually much lower than the air temperature, especially in the summer. A decrease in temperature causes the newly laid pipe to contract, which will probably be counteracted by the pipe absorbing moisture providing the back filling material is moist. In practice it is often difficult to procure enough water to wet the trench or back fill. In this case pipe should not be laid in the hottest weather. It sometimes happens that the pipe will expand enough when saturated after being filled with water to prevent trouble with contraction cracks. Accordingly water should be let into a newly laid pipe line as soon as possible. This subject will be discussed more fully under another heading.

After the trench is dug, and the pipe to be laid strung along the side of it, one expert pipe layer with two helpers will sometimes lay as much as 1,200 feet of 8- to 12-inch pipe in a day, but 800 feet is a good day's work for an average crew. Four men will lay the pipe and partially backfill the trench. Four men are usually needed to lay pipe from 14 to 18 inches in diameter, and will average 300 to 500 feet of this size in a day. Five to seven men will lay from 300 to 500 feet of 24-inch pipe in a day.

There is wide variation in the cost of laying pipe and the quantity of mortar used in making the joints. If heavy bands are made at the joints for high pressure lines, it often costs from 25 to 50 per cent more to lay the pipe. One pipe manufacturer estimates that one sack of cement, made into one to one and a half mortar, will lay 350 feet of 6-inch pipe, 270 feet of 8-inch, 200 feet of 10-inch, 160 feet of 12-inch, and 70 feet of 20-inch pipe. If bell-ended pipe is used, similar to the ordinary clay sewer pipe, more mortar is needed.

CAUSES OF FAILURE OF CONCRETE PIPE.

One of the most frequent causes of failure of concrete pipe is a poor grade of pipe. If the pipe is made of poor material, or a very

lean mixture, it is apt to split even under low pressures. A poor grade of pipe may appear to be in good shape when first installed, but may fail after a year or more due to softening of the concrete. It is common, however, to detect causes of failure as soon as the pipe is filled with water.

More or less seepage is common to most grades of hand-tamped pipe, but if it is not too pronounced it usually disappears in time. Such materials as silt, clay, or fine sand are often used to fill up the pores and prevent seepage. As mentioned above, pipe made of a dry mixture is more subject to seepage than wet-mixed pipe, and the joints are more difficult to make in a dry, porous pipe.

If the pipe is of good quality any leaks that occur are usually at the joints. When pipe is laid by inexperienced men leaks at the joints are common, caused by poor mortar connection or by the mortar falling from the joints when the pipe is being laid. Care should be taken to see that the joints are butted against each other, and that the mortar is squeezed firmly into place. Mortar will often fall out of the joints at the top of the pipe, and the fault may be difficult to detect, particularly in the smaller sizes. When pipe is banded and under pressure it is common for water to seep out between the band and the outside shell of the pipe. Water will sometimes seep quite a distance in this manner. This may be caused by a poor union between the abutting ends, or it may be due to dry, porous pipe. Bands or joints will crack if the pipe is not properly covered with earth, and for this safeguard moist earth is preferable.

Concrete pipe should not be injured by the roots of orchard trees unless cracks appear. Large roots of shade trees may heave the pipe and cause failure, or small, fibrous roots may enter the pipe and completely clog it. Tree roots sometimes enter the pipe at the connection of orchard risers, the risers being often loosened from the pipe by being hit with plow or cultivator.

Pipe lines sometimes fill with sand or trash, where the inlet is not properly screened or settling basins provided. If velocities are high enough the pipe will be flushed out without resorting to any special means. Otherwise blowoff valves should be installed.

Adobe soil will heave and crack and rupture pipe lines very much in the same manner as it affects lined ditches. Most pipe layers are skeptical of the success of concrete pipe laid in adobe soil, and some will not guarantee work under such conditions. In some cases the trouble has been overcome by covering the bottom of the trench with 2 to 3 inches of sand. A good practice seems to be to dig the trench deeper than in sandy loam or sandy soil, and to take extra precautions in forming the joints. A minimum covering of 2 feet over the top of the pipe is sometimes specified in adobe soil.

Some soil will settle when first irrigated and this settlement will often allow the pipe line to settle also and cause cracks. If this type of soil is encountered, the bottom of the trench should be thoroughly soaked and settled before laying the pipe.

Probably the greatest trouble with breaks and leaks in concrete pipe lines is caused by expansion and contraction. It is common knowledge that concrete expands with a rise in temperature, but it is not so generally known that it also expands when saturated and contracts when becoming dry. It may surprise some to learn that a thoroughly air-dried pipe may contract as much in the process as it would under a fall of temperature of 100° F. In such cases cracks 0.18 of an inch every 25 feet or so are liable to appear. These cracks may close up when the pipe is refilled with water, or trash such as small particles of rock, sand or tree roots may enter and prevent closure.

The contraction due to pipe drying out often takes place after the pipe line has been in use for one or more seasons. For this reason it is common for a farmer to have to repair his pipe at the beginning of every irrigation season. The change of temperature in a pipe that is buried deep, especially when under the shade of large fruit trees, is very small. Usually, however, the pipe becomes thoroughly dried during the season of non-use and this drying out process is hastened when orchard distributing stands are left open.

In this connection it may be stated that a great deal of trouble is experienced where pipe is installed in desert regions. In such places the range of temperature and the drying-out process on the part of the pipe are at a maximum. A sudden contraction of 7 inches when a section of pipe was cut out is recorded. Expansion of pipe due to wetting will often crush diversion boxes or relief stands, and in extreme cases the pipe itself has crushed or telescoped. Pipe is also cracked at curves from the same cause. One manufacturer in the San Fernando Valley, Calif., has recorded a case where a 12-inch pipe laid in a straight line for a distance of 4,000 feet, expanded 18 inches through a diversion box. There are numerous cases where such stands have been crushed due to expansion of the connecting pipe line.

If the pipe can be anchored, either by concrete anchors at intervals or by reinforcing the bottoms of relief or diversion stands, failure by expansion may be guarded against, since concrete in compression should have sufficient strength to prevent the crushing of the pipe. On the other hand concrete is relatively weak in tension and the pipe is certain to crack when sufficient contraction occurs. The spacing of contraction cracks will depend upon the strength of the pipe and joints, and the force tending to hold the pipe in place. The

weight of the pipe and earth pressure over it are usually the forces tending to prevent the pipe moving, therefore contraction cracks will occur when the strength of the pipe in tension is not sufficient to pull a certain length of pipe. There are a number of formulae for estimating the distance apart that contraction cracks will appear, but no records have been found where experiments were carried on in the field. It is probably safe to expect pipe of small diameters to crack about every 25 to 40 feet when laid under unfavorable conditions and subjected to sufficient contractive power. Contraction cracks usually appear at the joints, although at times the pipe is broken.

There are two methods of reducing to a minimum the trouble with expansion or contraction. The first is to lay the pipe under favorable conditions, the second is to provide expansion joints at frequent intervals.

Favorable conditions for laying concrete pipe depend upon temperature, moisture in the pipe when laid, and moisture in the ground. Pipe laid in winter, when the ground is moist from rains, seldom gives trouble, especially if the pipe is kept continually full of water after being laid. Pipe laid in sandy soil, when the ground is hot and dry, is almost certain to develop contraction cracks unless water is turned in promptly. If it is necessary to lay pipe in hot, sandy soil, the trench should be deep and the backfill kept moist until water can be turned in. As bands and joints set very rapidly, pipe can often be filled with water 24 hours after laying. Heavier soil containing moisture will protect pipe from drying out. If the pipe is dry when laid, and the soil is dry and warm, there will probably be little change in the length of the pipe until it is filled with water, but when the pipe is thoroughly soaked there is liable to be considerable expansion. This accounts for expansion troubles that are so common under desert conditions. If the movement of pipe due to expansion is prevented, no trouble may be experienced thereafter, as the elasticity of the concrete may prevent contraction when the pipe is dried out again after the first irrigation. Some engineers have advocated that the pipe be wetted before laying in desert soil, but this would not seem to be good practice because if the soil is dry the pipe would soon become dry too, causing contraction cracks, before the water was turned in. It would seem a good plan to have the pipe as cool as practicable before laying under the above conditions, as the pipe that is placed along the trench in the hot sun before being laid cools off when covered with the backfill, and this will cause contraction. It should be possible in many cases to lay pipe so that expansion due to wetting the pipe when first laid in the trench will counteract the contraction due to cooling off when covered with soil. The safest procedure to be followed in laying pipe in the desert in the summer is to do the work at night, when the temperature is low,

but it is desirable that all irrigation systems in such localities be installed in the fall or winter. In any case it is best to allow the pipe to assume its permanent length in the trench before the mortar in the joints has thoroughly hardened, and to fill the pipe soon and keep it full of water continually thereafter.

There is one 8-inch stock, unreinforced concrete pipe laid in the desert soil of Antelope Valley, Calif., that is under a continual pressure of about 80-foot head. No leaks have been observed in this pipe since the water was turned in over two years ago. This pipe is always full, the water which it conveys being used for domestic purposes as well as irrigation. Other pipes in the same locality are continually giving trouble, and in most cases such trouble can be traced to the alternate wetting and drying out of the pipe.

There is little doubt that the best engineering practice to be followed in laying concrete pipe is to provide expansion joints at frequent intervals. Effective expansion joints will allow the pipe to be in longitudinal equilibrium at all times, and thus protect the pipe from stresses which may cause failure. Practically all engineers have provided expansion joints in buildings, retaining walls, concrete bridges, and other important structures, yet such joints in concrete pipe lines are comparatively unknown. Of course, temperature changes are less in buried concrete pipe than in many structures, but as has been stated, expansion due to a saturated or even moist condition may be considerable.

It is not difficult to provide expansion joints for pipe that does not carry water under pressure. One contractor has telescoped an 8-inch pipe in a 12-inch, calking part of the space between the pipe with burlap and then filling with tar or asphalt, finishing off the joint by calking with burlap. This joint will answer for low heads. Tar or roofing paper has also been used for pipes under very low heads or running less than full. The tar paper is wired to the outside of the adjoining pipes over the joint, the pipe is not butted close together, and the space filled with an asphalt mixture. A strip of galvanized sheet metal is placed under the joint inside the pipe to hold the asphalt in place. Clay pipe or concrete pipe made with a bell end is sometimes laid by pouring hot asphalt into every joint. There should be no expansion troubles with this installation if the pressure is not sufficient to force the asphalt mixture from the joints. Expansion joints have been made by painting heavy oil over one end of the abutting joints and then cementing a band of mortar over the joint, but it is doubtful if this joint will slip except under the most favorable conditions. Expansion joints have also been formed by placing an oiled thimble of galvanized sheet iron in the center of the shell of a joint of pipe after one-half of the pipe has been made and while the concrete is still in the molds, pouring asphalt over the ends of the

joint after the thimble has been forced halfway down into the lower half of the pipe, as shown in figure 4. The remainder of the joint is then finished. The concrete is expected to slide over this metal strip. Joints made in this manner in the laboratory leaked badly when under pressure where a prepared asphalt compound was used to coat the metal strip. If oil be used, it is probable that the bond would be too strong to allow slipping.

A simple expansion joint (fig. 5) has been tried out that seems to work well under all conditions. A strip or thimble of copper or lead is welded to make a continuous ring, which is about 4 inches wide and the same diameter as the center of the shell of the pipe. This strip is then crimped and cemented into a short section of pipe. When the pipe expands or contracts the crimp in the metal gives. Such joints have been found to be water-tight under 125 feet head.

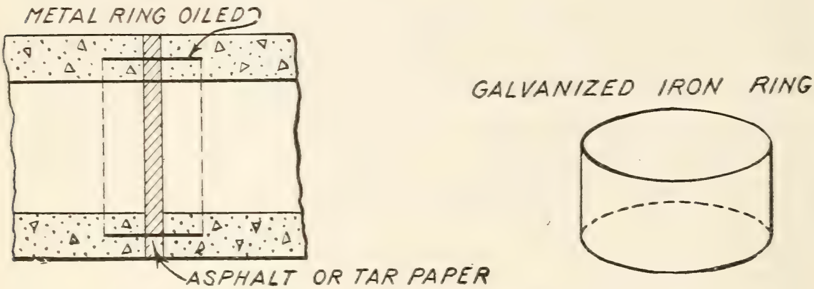

FIG. 4.—Expansion joints for very low pressure.

Expansion joints are made and sold by steel pipe manufacturers that are adapted to the use of steel pipe. Such joints are expensive and are not advisable except under unusual conditions. Bolted joints fitted with rubber gaskets that are commonly used with riveted steel pipe can be used, and will be found to be much cheaper than the commercial expansion joints. Cast-iron collars that fit over the joint and are packed with oakum and asphalt, represent another type. One engineer has suggested using a short length of light weight corrugated iron pipe to be cemented at intervals in the concrete pipe line. Any expansion joint made with steel or iron is subject to corrosion, however.

Alkali will sometimes disintegrate concrete drain tile and may attack a porous, dry mixed pipe when used for irrigation. Drain tile is subjected to the most unfavorable conditions. The tile is laid where the alkali salts are continually being drained into it. The joints are not cemented and the tile is often only partly full of water. Drain tile is often made inferior to irrigation pipe, the small sizes being made of sand and cement only, with a deficiency of

cement. It may not be tamped properly and is nearly always made from a very dry mixture.

Irrigation pipe if kept full of water free from alkali salts, tends to exclude ground water containing alkali, from the shell of the pipe. If the pipe is under pressure, there seems to be little chance of alkali salts entering the pores of the pipe from the outside. Then too, irrigation pipe is usually laid on the higher parts of the land that are freest from alkali. Culverts of poor grade of concrete pipe used for road crossings have been observed to be almost eaten away when exposed to water strongly saturated with alkali. On the contrary, irrigation pipe of a good grade of concrete buried in compact soils impregnated with alkali adjacent to these culverts has been found to be entirely sound.

Briefly stated, the sulphates and magnesia salts seem to be the most harmful, but dense concrete made from wet mixtures is usually very little affected. It has been suggested that drain tile laid in alkali soils be made at least of a one to three mixture of cement to aggregates. It is probable that a much leaner mixture can be used for low-pressure pipe, if care is taken to grade the sand and rock in the aggregate. Rock dust, clay, or even silt may be added to the mixture to make an impervious pipe. In any case the pipe should be made from a wet mixture and thoroughly tamped or compressed.

Another source of failure in concrete pipe is the rupture of the pipe due to sudden increases of pressure, which may be caused by water hammer. Water hammer is especially troublesome where water is pumped directly into a pipe line and where the pipe is of considerable length and runs up grade from the pump. If the pump is started and stopped gradually, the extra pressure due to water hammer will be slight, but if the pump is suddenly stopped, pressures will sometimes increase two or even three times above normal. The same thing may be caused if a valve in the discharge main from the pump is suddenly closed. Increased pressures may be recorded in any pipe that is running at full capacity under pressure, if a valve is suddenly closed.

The usual method of preventing breaks from water hammer is to provide a standpipe. The standpipe or relief stand should be high enough to allow for grade and friction in the pipe when running at full capacity and should be about the same diameter as the main, although large mains are often protected by standpipes of considerably less diameter than the main. If pressures are increased suddenly, water will rise in the standpipe and overflow, thus relieving the pressure in the line. For stands 25 feet in height and under, concrete pipe can be used. It is good practice to reinforce the first two or three joints if high stands are used, or pipe of larger diameter can be used for the first two or three joints. One standpipe near

Saugus, Calif., is 80 feet high and was built to protect a 16-inch reinforced concrete pipe that runs gradually up grade for over 2,000 feet. The standpipe is made of 12-inch riveted steel pipe, supported by a steel windmill tower.

Open boxes of concrete are built to about 15 feet in height and act as relief stands and at the same time are used as diversion boxes or for measuring water over weirs.

Where pressures are too great to permit the installation of a standpipe, it is common to use air drums to relieve back pressure. Air drums are chambers that are partly full of air, the elasticity of the air preventing excessive pressures on the pipe. Air chambers have been used successfully in some installations, but there are so many cases of the air chamber being waterlogged at a critical time that a

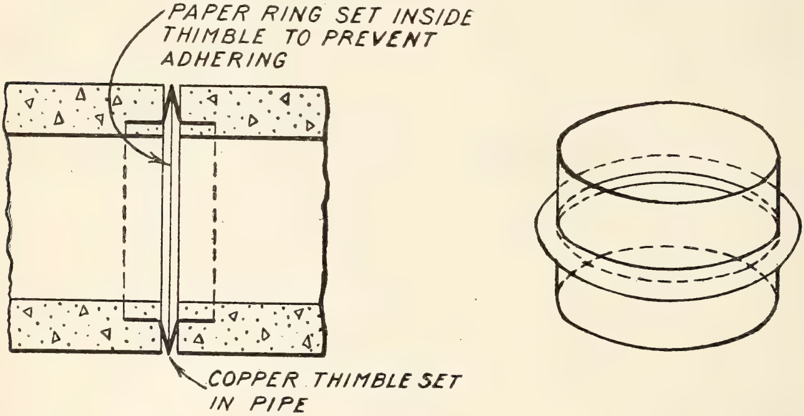

FIG. 5.—Expansion joints for high pressure.

number have been replaced by relief stands. Some air drums are equipped with an automatic air pump that keeps the chamber filled with the proper proportion of air, but as any such apparatus is liable to get out of order, the air drum may be worthless when needed the most. There are some instances on record where air pumps have delivered an excess of air which has caused large bubbles of air to collect in the main.

Relief valves have also been used. These are so adjusted that an excess of pressure will open them and let out enough water to bring down the pressure in the pipe. Relief valves are not in great favor, however, as they may stick under high pressures or blow off under small variations of pressure which occur when a pump is directly connected to a main.

Check valves have been installed at intervals along a main leading from a pump but have met with little success. Unless provision is made to allow some water to escape at the pump when it is suddenly

stopped, it is not to be expected that enough water will run back to close a check valve. Water is incompressible and pressure alone may be transmitted back to the pump without any appreciable back movement of the water.

The Whittier Water Co. has equipped electric motors with heavy flywheels directly connected to centrifugal pumps, in order to reduce the water hammer. Gasoline engines have also been equipped with extra heavy flywheels, the engine being connected by gears to the pump. The function of a flywheel on an electric motor is to prevent a sudden stopping or starting of the pump, as the momentum of the flywheels will keep the pump going for about one minute after the power is turned off. Heavy flywheels on gasoline engines serve the same purpose. If a belt is used to connect engine or motor with pump, however, the flywheel would be of no use in case the power is suddenly shut off, as the belt would then slip off or break.

The engineer in charge of this work has reported excellent results from the use of flywheels, and has installed them in many of the pumping plants of the company. He has torn down standpipes as being less effective, and is of the opinion that blow-off valves and check valves are either worthless or else a never-ending source of annoyance.

When concrete pipe is directly connected to a centrifugal pump, the best practice is to eliminate any check valve and substitute a slow-closing gate valve on the discharge pipe of the pump. When the pump is started the valve can be opened slowly and thus prevent a dangerous increase of pressure on the pipe. The valve can be closed slowly when the pump is stopped and thus prevent water hammer. In case of an accidental stoppage of the power water will run down the well until the valve is closed.

DESIGN OF PIPE SYSTEMS FOR IRRIGATION.

The design of an irrigation system for a new tract where pipe is to be used differs in many respects from that where all water is carried in open ditches. The chief difference in design is due to the fact that well-made concrete pipe may be depended upon to carry water under pressure. Thus it is possible to eliminate devious routes of main ditches that must be located on grade. It is best, however, to make accurate contour surveys of large tracts that are to be irrigated by pipe. Contour maps should also be made of all possible routes of main lines and each subdivision should have contour intervals plotted close enough to enable the engineer to design economically the sizes of laterals and their location and to indicate how the individual units should be graded for effective irrigation.

Five-foot contour intervals may be close enough for estimating the location of the main pipe in hilly country, but it may be necessary to plot 1-foot or even 6-inch contour intervals on flat valley land. Furthermore the entire system should be designed before any construction work is begun.

Tracts for new colonies under the control of the Land Settlement Board of the State of California have been carefully surveyed throughout. The location of pipe lines has been determined and the sizes and location of each subdivision carefully considered. Contour intervals have been plotted accurately enough to allow all surface grading to be laid out before the farm is ready for water. The size of each subdivision is determined by the character of the soil and the methods adopted for irrigation and drainage. The location of the laterals is also determined by the prevailing grades of each unit to be watered and the kind of crops to be grown. Land for alfalfa usually has comparatively flat slopes, while orchard land may be very uneven providing pressure pipe is used.

Hilly land that has recently been subdivided for citrus orchards is frequently irrigated with little or no grading, even though the separate tracts may be very uneven. In this case pipe lines are constructed along ridges, feeding all the high knolls. Tree rows may be laid out in squares, or may be set out with respect to contours only. If contour or terrace planting is necessary it is usually possible to irrigate in two directions from one field lateral.

The sizes of pipe needed for a given tract will depend upon the acreage to be served, the grades of the pipe lines, the smoothness of the interior surface of the pipe, the water requirements of crops, the character of the soil, and the slope of the land. If the source of water is a reservoir at a considerable elevation above the lands to be irrigated, it may be possible to install pressure pipe that will carry water at a high velocity. If pressures exceed 50 feet in head it is common to install steel, reinforced concrete, or wood pipe. It is often practicable, however, to control the pressure of the main by suitable relief stands so that concrete pipe of larger diameter can be used. The latter practice is usual in recent installations. The smoothness of the interior of the pipe will also affect its carrying capacity.

The following table is compiled from data collected in the field by Fred C. Scobey, senior irrigation engineer of the Bureau of Public Roads.[3] The table is not complete but has been arranged to give approximate carrying capacities of concrete pipe under ordinary working conditions and for average pipe. Especially smooth pipe will have larger capacities and very rough pipe much lower. For average conditions small sizes should not be figured too closely. Probably pipe up to 12 inches diameter should be computed to

[3] "The Flow of Water in Concrete Pipe." Bulletin 852, U. S. Dept. of Agr.

carry about 20 per cent more water than shown by table, especially where there is danger of any clogging by débris, or pipe is very rough.

Table gives the carrying capacities of concrete pipe in miner's inches computed to the nearest 5 miner's inches.[1]

[Fall in feet per 100 feet.]

Diameter of pipe.	0.1	0.2	0.3	0.4	0.5	1.0	2.5	5.0
	Miner's inches.	*Miner's inches.*	*Miner's inches.*	*Miner's inches.*	*Miner's inches.*	*Miner's inches.*	*Miner's inches.*	*Miner's inches.*
6 inches	10	10	15	20	20	30	45	60
8 inches	20	25	35	40	45	60	85	140
10 inches	35	50	60	70	80	110	180	250
12 inches	60	80	110	115	120	180	275	
14 inches	85	120	150	170	200	275	400	
16 inches	120	170	210	235	275	400	600	
18 inches	160	230	285	330	450	550	825	
20 inches	225	310	380	435	500	700	1,100	
22 inches	275	400	485	525	625	900	1,400	
24 inches	350	500	620	710	800	1,150		
30 inches	650	900	1,100	1,275	1,425			

[1] One miner's inch is here equivalent to the one-fiftieth part of a second-foot and is nearly equal to 9 gallons per minute.

Engineers and pipe contractors will have no trouble in interpreting the above table, but for the convenience of irrigators without engineering experience, a few examples will be given to enable them to estimate sizes of pipe for various conditions.

The retarding influence to flow of water known as friction is common to all pipes, the intensity of the friction increasing with the velocity of the water and the roughness of the pipe. If the pipe is laid down grade the fall may be sufficient to overcome friction. When the water is pumped if the fall is not enough to carry the desired quantity then the water will rise in the standpipe at the entrance until there is sufficient head to force the water through. Of course if the stand is not high enough water will spill over the top. If the pipe runs up hill, when water is pumped, the delivery box or relief stand at the pump end must be high enough to overcome the difference in elevation between the entrance and outlet of the pipe, plus the head required to overcome friction in the pipe. In practice such standpipes should not be high enough to develop unsafe pressures on the pipe.

Example 1.

Assume that an irrigator has acquired the right to the use of 200 miner's inches of water and wishes to install a pipe to carry this amount to his farm, a distance of 2,000 feet. If levels show there is a total fall of 6 feet between entrance and outlet, he will have a fall of 0.3 foot per 100 feet. From the table under vertical column of 0.3 (fall per 100 feet) it is seen that a 16-inch pipe will carry 210 miner's inches. If he can fill the standpipe at entrance 4 feet deep, he will have 4 feet additional head on the pipe, or a total head of 10 feet (including fall). This gives him 0.5 foot fall per 100 feet. The table

shows that a 14-inch pipe will carry 200 inches under these conditions. (In taking levels the actual difference in elevation between the point of entrance and the point where water is discharged must be taken. If water is discharged over distributing stand, the elevation of top of the stand must be taken.)

Example 2.

Assume an orchard lateral is run down a steep grade of 5 feet per 100 feet, which is not uncommon in hillside tracts. It will be seen from the table that a 6-inch pipe will carry 60 miner's inches of water, but if a lateral is taken off this line that falls only 0.1 foot per 100 feet, the table shows that a 12-inch pipe will be needed to carry the same amount of water. If the lateral runs across a 10-acre tract or 660 feet and the delivery stand carries a head of 6 feet, we will have a total head available of 1 foot per 100 feet, requiring only an 8-inch pipe.

If grades vary, where open stands are frequent, allowing little or no pressure in the pipe, the diameters of the pipe should vary with the grade, especially where the variation is considerable. On the other hand, if the pipe is under pressure from one end to the other and there are no relief stands, the pipe should be the same diameter throughout its entire length.

Too many pipe contractors guess at the sizes of pipe to use and pay little or no attention to grades. Usually however, they are on the safe side where water runs down hill although the pipe may be several sizes larger than necessary. On the other hand, it is common for inexperienced men to install undersized pressure pipe that is used for pumping, which means that the pump must be burdened with additional lift in order to overcome the excessive frictional resistance in the small pipe. If concrete pipe is directly connected to a pump, the pipe may burst from excessive pressures, although the actual elevation between the pump and outlet may be small, the total head due to excessive friction causing failure. For example, it can be seen from the table that if 250 miner's inches are pumped into a 10-inch pipe that is laid on the level, friction will cause a head of 5 feet for every 100 feet length, or a total head at the pump of 50 feet, if the pipe is 1,000 feet long.

It is wise to keep concrete pipe under as low heads as possible and where pressure is to be applied care should be taken to get the best quality of pipe. It is often possible to control pressures on pipes especially where there is a constant down grade. If the pipe is not fitted with outlets open at the top, or other means of relieving pressure such as overflow stands, open diversion boxes and so on, the pressure on the lower end of the pipe will increase as the pipe fills, and the lower sections may fail from excessive pressure. It is a

mistake to depend on valves that may be closed entirely to relieve pressures, as such valves may all be closed at one time. Safety devices will be discussed under another heading.

SETTLING BASINS AND SCREENS.

Settling basins (fig. 6) should be installed in a pipe line where vegetable or earthy material may clog the pipe. Settling basins are often necessary where water is carried from a hilly territory in an open ditch, as such conditions are favorable for picking up débris, and where the ditch terminates at the beginning of a pipe line. It is usual in this case to install the basin at the junction of the ditch and pipe line as shown in figure 7. The dimensions of the settling basin depend upon the quantity of solid material transported in the ditch or pipe line. It must be large enough in area to check the velocity of the water sufficiently to allow the solid particles to settle, and deep enough to collect sand and other trash for a considerable period, otherwise it will require cleaning at too frequent intervals. Ordinary sand is transported in a pipe or ditch at a velocity of about one-half to two-thirds foot per second and fine gravel at an average velocity of about 1 foot per second. If the grades are such that velocities suddenly become too low to carry solid particles, settling basins should be installed or the pipe is liable to become clogged. Small settling basins, such as are installed at the intake of a field lateral with a main pipe or ditch, are usually cleaned out by hand. Large basins in main ditches should be located so that the sand can be flushed out. If a ditch runs parallel to a river bed or natural drain it is usual to install basins so that the waste will flush into the river or drain. Basins are also provided at points where the pipe crosses a ravine or other waterway. In this case solid materials can be flushed out readily. In case of flat grades, however, it is necessary to clean out the collected material by hand.

Screens are often installed with settling basins for small lateral ditches that carry a large quantity of floating trash, in order to prevent orchard valves from becoming clogged. Some are placed in the basin at an angle of about 30 degrees to the vertical. In other cases multiple screens (fig. 6) are inserted in grooves. The one nearest the intake pipe may be of chicken wire having about $1\frac{1}{2}$ inch clear openings and each successive screen having a finer mesh of wire down to one-half or one-eighth of an inch. The first screen collects the larger trash such as leaves and small floating sticks, while the other screens catch the finer particles. The screens are made on frames that slide in grooves in the sides of the concrete box and can be readily removed and cleaned.

If trash is carried in large quantities it is often necessary to devise some method of greatly increasing the screened area. This may be

done by building a screen completely around the outlet pipe. Some screens are built in the form of a long narrow trough which is screened on all sides, the outlet being beneath the screen. Such a screen can be set in an open ditch that is widened out a little at the pipe inlet.

Screens have also been designed that are self cleaning, reliance being placed on the velocity of the water to keep the screens open.

Care should always be taken to prevent trash entering a ditch or pipe line where water is finally distributed through orchard hydrants having small openings. It is especially necessary to take proper

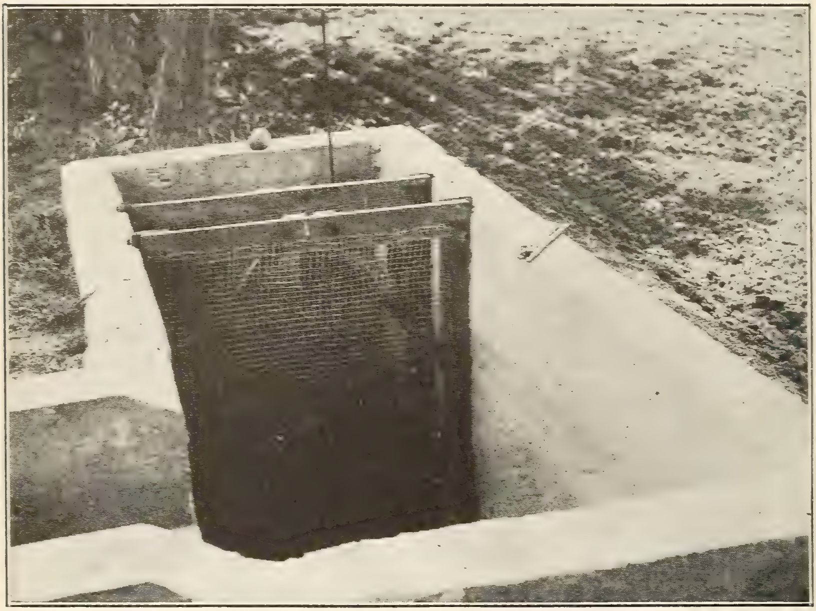

FIG. 6.—Settling basin and screens.

precautions at the intake where the water is diverted from a flowing stream. For comparatively small heads of water it is sometimes possible to bury the first 20 or 30 feet of pipe under the stream bed laying the pipe with open joints and covering it with gravel. This will prevent all floating material entering the pipe and should keep out the sand. Some comparatively large mains have been protected at the intake in this manner.

Open ditches bordered by shade trees are continually gathering leaves which are particularly harmful in clogging screens, as the leaves will flatten out against a fine mesh screen and may completely obstruct the flow of water.

Where pipes are fed by open ditches and have sufficient grade so that the velocity of water will transport sand or small gravel, the

entrance to the pipe is commonly protected by iron bars set on an angle in front of the pipe entrance. The bars may be spaced 6 inches or more apart. Such protection will prevent boards and large tree branches entering the pipe.

AIR VENTS.

When air is drawn into a pipe carrying water, being lighter than the water, it tends to collect at the highest points of the line. Such accumulations of air lessen the water-carrying capacity of the pipe and may obstruct it altogether. To guard against occurrences of this kind means should be provided to allow the entrapped air to escape into the atmosphere. One of the safest and best means of

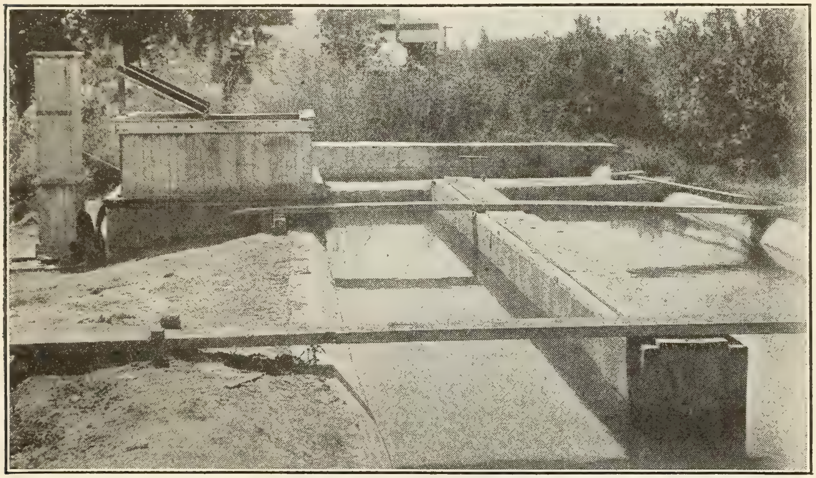

FIG. 7.—Showing long screen at junction of open ditch and pipe line. Weir box and automatic register at left of picture.

doing this is by the insertion of standpipes at all points where air is liable to collect. These standpipes need not be large for the average sizes of pipe. They are not only automatic but continuous in their action. For lateral pipes a galvanized-iron pipe 1 inch in diameter and covered with a perforated cap and protected by a substantial post makes a cheap and serviceable air vent. It is also good practice to get rid of the air as soon as it enters the pipe by inserting standpipes near each intake, care being taken in all cases to extend the air pipe far enough above the pipe so that its top will be well above the hydraulic grade line, or in other words, above the head to which water will rise.

Where standpipes can not be used the confined air may be released by the use of automatic air valves which can be inserted on pipes under medium and high pressures. One of the simplest of these is a spherical rubber ball which is pressed tightly against the circular

opening when the pipe is full of water, but which falls down when the water is lowered by the collection of air. Another kind operates by means of a float and lever, the lowering of the float causing the air valve to open and discharge the entrapped air.

RELIEF STANDS.

Where steel or wood pipe is used to carry irrigation water, it is not customary to make provisions for relief of pressure except in long lines that are laid on heavy grades. Concrete pipe, however, unless reinforced is only intended for low heads and provision must be taken to prevent high pressures.

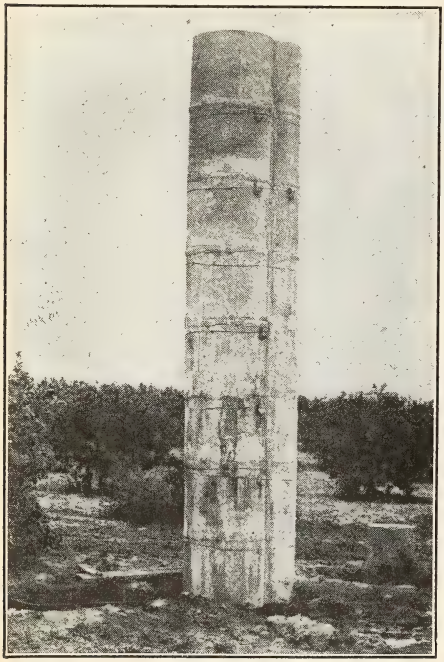

FIG. 8.—Overflow and relief stand.

Where a pipe is laid down a long grade, and is large enough to carry all the water running less than full, there will be little or no head on the pipe when outlets are provided at frequent intervals with their tops always open, but as it is usual to provide shut-off gates to divert water, pressures may increase to such an extent as to break the pipe when all gates are closed unless proper precautions are taken to guard against such conditions arising.

The ordinary open diversion box is fitted with gates that divert water by closing the gate on the outlet pipe only, the gate being kept tight by water pressure against it. In this case the water can not back up in the pipe and form a dangerous head, since the water in the box will overflow, but where the pipe will withstand 20 to 30 feet head, and it is desirous to force water along a lateral that runs up hill 15 feet or more, it is not feasible to construct the ordinary diversion box, as such a box would have to be too high to be conveniently accessible. In this case, pressure gates may be provided that close the inlet pipe providing there is an open stand above the gate that will relieve the pressure. Another plan is to provide an overflow stand that will maintain a constant head at the point of diversion, the excess water spilling over into the main. Two vertical

open stands made of concrete pipe cemented together may be used for this purpose. The water will rise in the pipe connected to the inlet, and flow over a crest or notch into the other pipe, and thence into the main (figs. 8 and 9). The lateral pipe leading from this stand requires no gate, as the pressure will remain constant, allowing no excessive pressures to accumulate in the lateral. If a lateral slopes down grade from an overflow stand it is usual to provide a shut-off gate where the lateral branches off from the stand. The gate may be set in a low auxiliary stand that is cemented to the side of the main relief stand. Some relief stands consist of one large standpipe of sufficient diameter to allow an overflow pipe being placed inside of it (fig. 10). Some orchard laterals have a 12-inch stand 6 to 18 feet high fitted with a 6-inch spillway pipe inside, the 6-inch pipe extending to a foot or so of the top of the 12-inch pipe. In this case water is diverted to the side lateral from the 12-inch pipe, the excess of water spilling down the 6-inch pipe into the main. There are a number of modifications of this principle that will be taken up in detail under the subject of diversion boxes and pipe structures.

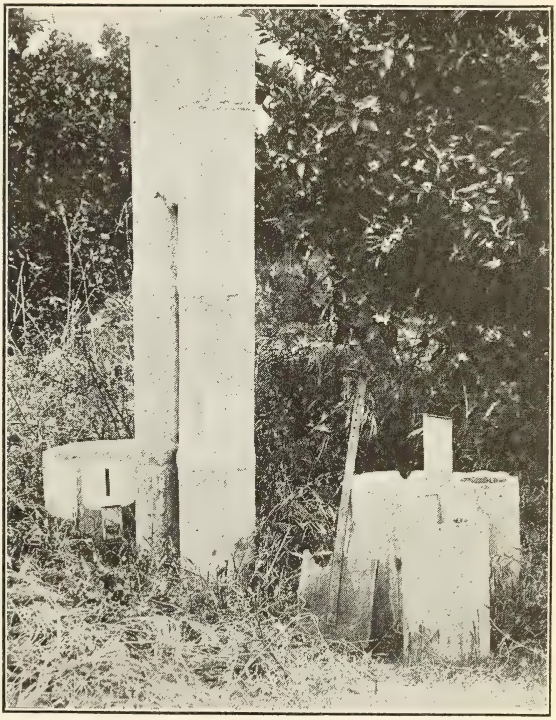

FIG. 9.—Overflow pipe in rear and small diversion box in front.

Nearly all measuring devices act as relief stands, especially weirs, miner's-inch boxes, and ordinary recording irrigation meters, as such devices are installed to allow the free flow of water over a crest in an open box.

MEASURING DEVICES FOR PIPE IRRIGATION SYSTEMS.

A number of devices are in use to measure the flow of water through pipes and laterals and from pumping plants and reservoirs. Of these the following are briefly discussed—Venturi meters, weirs,

miner's-inch boxes, automatic registers, and other mechanical recording devices.

Venturi meters.

These make use of the Venturi principle by forcing water through a small throat in a pipe, thereby converting most of the static into velocity head. By keeping a continuous record of the normal static pressure and also the pressure at the throat the flow of water at any time can be computed for a meter of a given size. Meters of this type are installed on main pipe lines when it is desired to keep a continuous record of the total quantity of water delivered to any system. They might also be installed advantageously on lateral pipe lines were it not for their first cost, since they have no moving parts liable to be obstructed or clogged by sand, leaves, or other material carried by the water.

Fig. 10.—Twelve-inch overflow stand with 6-inch pipe inside.

Weirs.

The weir is the most commonly used device for measuring water in open ditches and canals. It is more difficult to adapt it to pipe systems, and when this has been attempted due consideration has seldom been given to the effects produced on the accuracy of the measurement by seemingly trivial changes from the standard specifications. One of the essential requirements of the weir is that the water shall approach the weir notch at a slow velocity and unaffected by eddies or cross-currents. These conditions are seldom fulfilled when water issues from a pipe directly above the weir.

Several years ago, a large number of experiments were conducted by V. M. Cone of this bureau at the hydraulic laboratory at Fort Collins, Colo., on the flow of water through weir notches.[4]

In figure 11 is outlined the inside dimensions of a standard weir box to measure water within 1 per cent of accuracy in accordance with the different volumes specified in Table 1. In Table 2 is given in cubic feet per second the discharge through rectangular weirs from 1 to 4 feet in length and for varying heads.

Table 3 gives the percentage of error which occurs when changes from the standard form are introduced. Thus the effect of side contractions (C in figure 11) is seen in the increase in error of a 1-foot weir and a 6-inch head from less than 1 per cent to 4 per cent when the distance of the sides from the end of the crest is reduced from 2 feet to 6 inches as shown in figure 12.

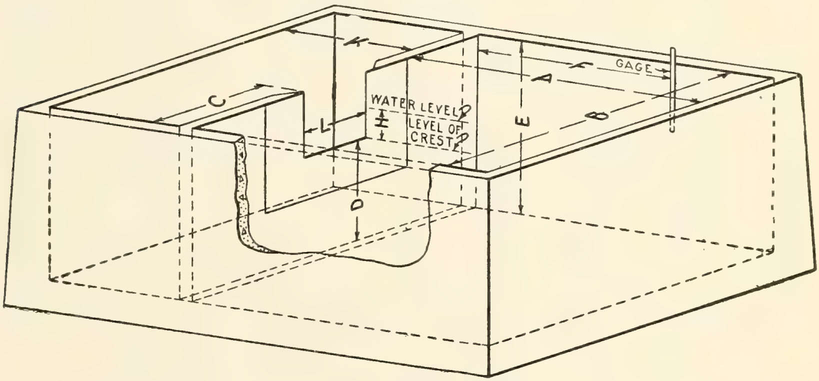

FIG. 11.—Standard 18-inch weir based on dimensions given in table.

TABLE 1.—*Weir-box dimensions for rectangular notch weirs.*

[All dimensions in feet. The letters at the heads of the columns in this table refer to figure 11.]

RECTANGULAR WEIRS.

Flow (second-feet).	H. Maximum head.	L. Length of weir crest.	A. Length of box above weir notch.	K. Length of box below weir notch.	B. Total width of box.	E.[a] Total depth of box.	C. End of crest to side.	D. Crest to bottom.	F.[b] Hook-gauge distance.	G.[c] Hook-gauge distance.
½ to 3	1.0	1	6	2	5½	3½	2¼	2	4	2
2 to 5	1.1	1½	7	3	7	4	2¾	2½	4½	2
4 to 8	1.2	2	8	4	8½	4½	3¼	2¾	5	2½
6 to 14	1.3	3	9	5	12	5	4½	3¼	5½	3
10 to 22	1.5	4	10	6	14	5½	5	3½	6	3

[4] For further information the reader is referred to Farmers' Bulletin 813 on the Construction and Use of Farm Weirs, by V. M. Cone.

[a] This distance allows for about ½ foot freeboard above highest water level in weir box.

[b] Equals distance from crest upstream to gauge.

[c] Equals distance from end of crest over to gauge.

TABLE 2.—*Discharge tables for rectangular weirs.*

Computed from the formula $Q=3.247\,l\,H^{1.48}-\dfrac{0.566\,l^{1.8}}{1+2\,l^{1.8}}\,H^{1.9}$.

Head in feet.	Head in inches.	Discharge in cubic feet per second for crests of various lengths.					Head in feet.	Head in inches.	Discharge in cubic feet per second for crests of various lengths.				
		1 foot.	1.5 feet.	2 feet.	3 feet.	4 feet.			1 foot.	1.5 feet.	2 feet.	3 feet.	4 feet.
0.20	2 3/8	0.291	0.439	0.588	0.887	1.19	.86	10 5/16	2.46	3.72	5.01	7.59	10.19
.21	2 1/2	.312	.472	.632	.954	1.28	.87	10 7/16	2.50	3.79	5.10	7.72	10.36
.22	2 5/8	.335	.505	.677	1.02	1.37	.88	10 9/16	2.54	3.85	5.18	7.85	10.54
.23	2 3/4	.358	.539	.723	1.09	1.46	.89	10 11/16	2.58	3.92	5.27	7.99	10.71
.24	2 7/8	.380	.574	.769	1.16	1.55	.90	10 13/16	2.62	3.98	5.35	8.12	10.89
.25	3	.404	.609	.817	1.23	1.65	.91	10 15/16	2.67	4.05	5.44	8.25	11.07
.26	3 1/8	.428	.646	.865	1.31	1.75	.92	11 1/16	2.71	4.11	5.53	8.38	11.25
.27	3 1/4	.452	.682	.914	1.38	1.85	.93	11 3/16	2.75	4.18	5.62	8.52	11.43
.28	3 3/8	.477	.720	.965	1.46	1.95	.94	11 1/4	2.79	4.24	5.71	8.65	11.61
.29	3 1/2	.502	.758	1.02	1.53	2.05	.95	11 3/8	2.84	4.31	5.80	8.79	11.79
.30	3 5/8	.527	.796	1.07	1.61	2.16	.96	11 1/2	2.88	4.37	5.89	8.93	11.98
.31	3 3/4	.553	.836	1.12	1.69	2.26	.97	11 5/8	2.93	4.44	5.98	9.06	12.16
.32	3 13/16	.580	.876	1.18	1.77	2.37	.98	11 3/4	2.97	4.51	6.07	9.20	12.34
.33	3 15/16	.606	.916	1.23	1.86	2.48	.99	11 7/8	3.01	4.57	6.15	9.34	12.53
.34	4 1/16	.634	.957	1.28	1.94	2.60	1.00	12	3.06	4.64	6.25	9.48	12.72
.35	4 3/16	.661	.999	1.34	2.02	2.71	1.01	12 1/8	......	4.71	6.34	9.62	12.91
.36	4 5/16	.688	1.04	1.40	2.11	2.82	1.02	12 1/4	......	4.78	6.43	9.76	13.10
.37	4 7/16	.717	1.08	1.45	2.20	2.94	1.03	12 3/8	......	4.85	6.52	9.90	13.28
.38	4 9/16	.745	1.13	1.51	2.28	3.06	1.04	12 1/2	......	4.92	6.62	10.04	13.47
.39	4 11/16	.774	1.17	1.57	2.37	3.18	1.05	12 5/8	......	4.98	6.71	10.18	13.66
.40	4 13/16	.804	1.21	1.63	2.46	3.30	1.06	12 3/4	......	5.05	6.80	10.32	13.85
.41	4 15/16	.833	1.26	1.69	2.55	3.42	1.07	12 13/16	......	5.12	6.90	10.46	14.04
.42	5 1/16	.863	1.30	1.75	2.65	3.54	1.08	12 15/16	......	5.20	6.99	10.61	14.24
.43	5 3/16	.893	1.35	1.81	2.74	3.67	1.09	13 1/16	......	5.26	7.09	10.75	14.43
.44	5 1/4	.924	1.40	1.88	2.83	3.80	1.10	13 3/16	......	5.34	7.19	10.90	14.64
.45	5 3/8	.955	1.44	1.94	2.93	3.93	1.11	13 5/16	......	5.41	7.28	11.04	14.83
.46	5 1/2	.986	1.49	2.00	3.03	4.05	1.12	13 7/16	......	5.48	7.38	11.19	15.03
.47	5 5/8	1.02	1.54	2.07	3.12	4.18	1.13	13 9/16	......	5.55	7.47	11.34	15.22
.48	5 3/4	1.05	1.59	2.13	3.22	4.32	1.14	13 11/16	......	5.62	7.57	11.48	15.42
.49	5 7/8	1.08	1.64	2.20	3.32	4.45	1.15	13 13/16	......	5.69	7.66	11.64	15.62
.50	6	1.11	1.68	2.26	3.42	4.58	1.16	13 15/16	......	5.77	7.76	11.79	15.82
.51	6 1/8	1.15	1.73	2.33	3.52	4.72	1.17	14 1/16	......	5.84	7.86	11.94	16.02
.52	6 1/4	1.18	1.78	2.40	3.62	4.86	1.18	14 3/16	......	5.91	7.96	12.09	16.23
.53	6 3/8	1.21	1.84	2.46	3.73	4.99	1.19	14 1/4	......	5.98	8.06	12.24	16.43
.54	6 1/2	1.25	1.89	2.53	3.83	5.13	1.20	14 3/8	......	6.06	8.16	12.39	16.63
.55	6 5/8	1.28	1.94	2.60	3.94	5.27	1.21	14 1/2	......	6.13	8.26	12.54	16.83
.56	6 3/4	1.31	1.99	2.67	4.04	5.42	1.22	14 5/8	......	6.20	8.35	12.69	17.03
.57	6 13/16	1.35	2.04	2.74	4.15	5.56	1.23	14 3/4	......	6.28	8.46	12.85	17.25
.58	6 15/16	1.38	2.09	2.81	4.26	5.70	1.24	14 7/8	......	6.35	8.56	12.99	17.45
.59	7 1/16	1.42	2.15	2.88	4.36	5.85	1.25	15	......	6.43	8.66	13.14	17.65
.60	7 3/16	1.45	2.20	2.96	4.47	6.00	1.26	15 1/8	......	......	......	13.30	17.87
.61	7 5/16	1.49	2.25	3.03	4.59	6.14	1.27	15 1/4	......	......	......	13.45	18.07
.62	7 7/16	1.52	2.31	3.10	4.69	6.29	1.28	15 3/8	......	......	......	13.61	18.28
.63	7 9/16	1.56	2.36	3.17	4.81	6.44	1.29	15 1/2	......	......	......	13.77	18.50
.64	7 11/16	1.60	2.42	3.25	4.92	6.59	1.30	15 5/8	......	......	......	13.93	18.71
.65	7 13/16	1.63	2.47	3.32	5.03	6.75	1.31	15 3/4	......	......	......	14.09	18.92
.66	7 15/16	1.67	2.53	3.40	5.15	6.90	1.32	15 13/16	......	......	......	14.24	19.12
.67	8 1/16	1.71	2.59	3.47	5.26	7.05	1.33	15 15/16	......	......	......	14.40	19.34
.68	8 3/16	1.74	2.64	3.56	5.38	7.21	1.34	16 1/16	......	......	......	14.56	19.55
.69	8 1/4	1.78	2.70	3.63	5.49	7.36	1.35	16 3/16	......	......	......	14.72	19.77
.70	8 3/8	1.82	2.76	3.71	5.61	7.52	1.36	16 5/16	......	......	......	14.88	19.98
.71	8 1/2	1.86	2.81	3.78	5.73	7.68	1.37	16 7/16	......	......	......	15.04	20.20
.72	8 5/8	1.90	2.87	3.86	5.85	7.84	1.38	16 9/16	......	......	......	15.20	20.42
.73	8 3/4	1.93	2.93	3.94	5.97	8.00	1.39	16 11/16	......	......	......	15.36	20.64
.74	8 7/8	1.97	2.99	4.02	6.09	8.17	1.40	16 13/16	......	......	......	15.53	20.86
.75	9	2.01	3.05	4.10	6.21	8.33	1.41	16 15/16	......	......	......	15.69	21.08
.76	9 1/8	2.05	3.11	4.18	6.33	8.49	1.42	17 1/16	......	......	......	15.85	21.29
.77	9 1/4	2.09	3.17	4.26	6.45	8.66	1.43	17 3/16	......	......	......	16.02	21.52
.78	9 3/8	2.13	3.23	4.34	6.58	8.82	1.44	17 1/4	......	......	......	16.19	21.74
.79	9 1/2	2.17	3.29	4.42	6.70	8.99	1.45	17 3/8	......	......	......	16.34	21.96
.80	9 5/8	2.21	3.35	4.51	6.83	9.16	1.46	17 1/2	......	......	......	16.51	22.18
.81	9 3/4	2.25	3.41	4.59	6.95	9.33	1.47	17 5/8	......	......	......	16.68	22.41
.82	9 13/16	2.29	3.47	4.67	7.08	9.50	1.48	17 3/4	......	......	......	16.85	22.64
.83	9 15/16	2.33	3.54	4.75	7.21	9.67	1.49	17 7/8	......	......	......	17.01	22.85
.84	10 1/16	2.37	3.60	4.84	7.33	9.84	1.50	18	......	......	......	17.17	23.08
.85	10 3/16	2.41	3.66	4.92	7.46	10.01							

TABLE 3.—*Velocity of approach and percentage of error caused by different end and bottom contractions for rectangular weirs.*

B.	A.	Length 1 foot.				Length 1.5 feet.				Length 2 feet.				Length 3 feet.				Length 4 feet.			
Distance of bottom below crest.	Distance of sides from end of crest.	Head 0.6 foot.		Head 1 foot.		Head 0.6 foot.		Head 1 foot.		Head 0.6 foot.		Head 1 foot.		Head 0.6 foot.		Head 1 foot.		Head 0.6 foot.		Head 1 foot.	
		Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.
Feet.	*Feet.*	*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*	
3.0	2.5			0.132	0.77																
3.0	2.0			.157	.81			0.213	0.82			0.269	0.84			0.342	0.83			0.402	0.87
3.0	1.5			.196	.099			.260	1.08			.317	1.14			.399	1.22			.460	1.29
3.0	1.0			.260	1.40			.337	1.63			.398	1.81			.484	2.06			.543	2.22
3.0	.5			.40	2.94			.477	3.22			.540	3.44			.616	3.72			.661	3.88
2.5	2.5			.150	.74																
2.5	2.0			.178	.82			.242	.88			.302	.94			.391	1.04			.460	1.11
2.5	1.5			.224	1.05			.297	1.21			.362	1.34			.461	1.57			.528	1.69
2.5	1.0			.299	1.58			.385	1.89			.457	2.14			.553	2.50			.623	2.76
2.5	.5			.462	3.42			.549	3.73			.625	3.99			.704	4.25			.760	4.48
2.0	2.5	0.94	0.17	.175	.73																
2.0	2.0	.115	.26	.209	.84			.284	.97			.352	1.11			.458	1.30			.539	1.42
2.0	1.5	1.148	.39	.261	1.13			.348	1.42			.424	1.67			.538	2.01			.620	2.28
2.0	1.0	.188	.66	.353	1.83			.450	2.28			.535	2.63			.648	3.14			.733	3.52
2.0	.5	.288	2.05	.538	4.01			.646	4.46			.728	4.80			.829	5.17			.895	5.47
1.5	2.5	.119	.17	.208	.74																
1.5	2.0	.141	.30	.252	.94	1.91	0.53	.341	1.18	0.239	0.74	.424	1.41	0.308	1.07	.539	1.71	0.365	1.33	.638	1.98
1.5	1.5	.175	.40	.314	1.31	.234	.73	.418	1.74	.286	1.01	.512	2.12	.363	1.44	.648	2.65	.416	1.74	.750	3.07
1.5	1.0	.234	.76	.424	2.24	.304	1.24	.544	2.87	.361	1.62	.646	3.40	.435	2.12	.790	4.14	.489	2.49	.889	4.68
1.5	.5	.355	2.26	.648	4.80			.784	5.53			.885	6.09	.552	3.41	1.013	6.77			1.091	7.20
1.0	2.5	.154	.19	.260	.82																
1.0	2.0	.209	.36	.314	1.12			.427	1.57			.532	2.00			.694	2.69			.810	3.15
1.0	1.5	.229	.50	.385	1.59	.311	1.09	.528	2.37	.377	1.55	.645	2.99	.478	2.25	.820	3.91	.552	2.79	.952	4.60
1.0	1.0	.308	1.01	.525	2.83	.400	1.77	.688	3.86	.476	2.39	.825	4.73	.577	3.22	.999	5.87	.650	3.83	1.135	6.77
1.0	.5	.469	2.84	.822	6.00	.573	3.74	.994	7.29	.646	4.38	1.129	8.29	.735	5.15	1.298	9.55	.794	5.64	1.405	10.27
.5	2.5	.221	.25	.350	1.11																
.5	2.0	.265	.50	.417	1.45	.368	1.30	.575	2.40	.460	2.05	.720	3.27	.624	3.34	.943	4.62	.711	4.05	1.120	5.65
.5	1.5	.337	.94	.530	2.20	.453	1.94	.710	3.53	.555	2.84	.875	4.73	.705	4.17	1.119	6.50	.818	5.15	1.308	7.88
.5	1.0	.450	1.84	.716	3.83	.588	3.22	.930	5.65	.704	4.35	1.118	7.23	.862	5.92	1.380	9.40	.975	7.01	1.576	11.2
.5	.5	.695	4.63	1.120	8.25	.852	6.43	1.37	11.0	.970	7.79	1.58	13.3	1.112	9.40	1.83	16.01	1.208	10.50	2.01	18.0

TABLE 3.—*Velocity of approach and percentage of error caused by different end and bottom contractions for rectangular weirs*—Continued.

B.	A.	Length 1 foot.				Length 1.5 feet.				Length 2 feet.				Length 3 feet.				Length 4 feet.			
		Head 0.6 foot.		Head 1 foot.		Head 0.6 foot.		Head 1 foot.		Head 0.6 foot.		Head 1 foot.		Head 0.6 foot.		Head 1 foot.		Head 0.6 foot.		Head 1 foot.	
Distance of bottom below crest.	Distance of sides from end of crest.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.	Velocity of approach.	Per cent of error.
Feet.	*Feet.*	*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*		*Ft. per sec.*	
2.0	2.0			.250	1.19			.322	1.22			.386	1.24			.488	1.28			.561	1.30
2.0	1.5			.314	1.52			.397	1.70			.467	1.84			.575	2.08			.648	2.22
2.0	1.0			.422	2.40			.514	2.80			.590	3.15			.698	3.62			.769	3.92
2.0	.5			.655	6.16			.746	6.41			.813	6.61			.896	6.88			.951	7.01
1.5	2.5																				
1.5	2.0	0.158	0.84	.300	1.34	0.207	1.02	.388	1.49	0.251	1.21	.465	1.61	.321	1.45	.590	1.82	0.373	1.61	.680	1.98
1.5	1.5	.196	1.11	.378	1.78	.255	1.38	.477	2.10	.304	1.60	.562	2.40	.377	1.95	.693	2.85	.429	2.19	.785	3.17
1.5	1.0	.260	1.70	.508	2.89	.329	2.08	.622	3.53	.381	2.36	.714	4.06	.454	2.77	.844	4.79	.504	3.02	.937	5.31
1.5	.5	.400	3.32	.795	7.29	.469	3.83	.906	7.79	.518	4.20	.989	8.18	.580	4.66	1.094	8.64	.617	4.93	1.163	8.85
1.0	2.5																				
1.0	2.0	.205	.09	.374	1.60	.274	1.25	.489	2.06	.331	1.55	.586	2.44	.425	2.05	.758	3.13	.492	2.39	.804	3.55
1.0	1.5	.257	1.20	.471	2.20	.335	1.71	.601	2.92	.400	1.55	.710	3.55	.500	2.82	.888	4.53	.569	3.30	1.003	5.19
1.0	1.0	.344	1.84	.643	3.76	.434	2.60	.787	4.83	.501	3.17	.908	5.73	.607	4.06	1.083	7.07	.671	4.60	1.200	7.92
1.0	.5	.529	4.00	1.010	9.20	.622	4.92	1.159	10.28	.690	5.61	1.271	11.08	.770	6.41	1.410	12.09	.826	6.98	1.503	12.72
.5	2.5			.64	3.3			.818	4.8			.968	6.07			1.21	8.07			1.391	9.56
.5	2.0	.300	1.11	.508	2.30	.399	1.81	.660	3.64	.487	2.42	.799	4.87	.625	3.40	1.013	6.73	.725	4.09	1.202	8.39
.5	1.5	.377	1.51	.640	3.30	.492	2.55	.818	4.80	.589	3.44	.969	6.09	.737	4.79	1.210	8.08	.847	5.80	1.391	9.56
.5	1.0	.505	2.39	.864	5.40	.636	3.93	1.077	7.58	.750	5.30	1.258	9.43	.908	7.18	1.505	11.95	1.013	8.39	1.688	1.38
.5	.5	.782	6.03	1.390	11.89	.932	8.02	1.605	14.63	1.037	9.43	1.782	16.85	1.173	11.28	2.015	19.80	1.263	12.48		

When weirs are formed by the use of concrete pipe, the usual practice is to employ pipe too small in diameter in proportion to the length of the weir, thus departing at times very far from the standard weir, and introducing errors which may amount in certain cases to 5 per cent and more, a combination of this kind being shown in figures 13 and 14. If pipes are to be used for this purpose they should be of large diameter and of thin shells so as to permit the largest possible distance between the end of the weir notch and the inner surface of the pipe. According to standard dimensions and accurate measurement a weir 1 foot long would require a pipe 65 inches in diameter whereas if a 2-foot pipe is used for the same length of weir the discharge may be too large by 5 per cent.

In order that the water may approach the weir at a slow velocity and be freed from cross currents and eddies, baffle boards are frequently placed in the receiving chamber and the inlet pipe may be placed in a vertical position and at right angles to the feed pipe.

Another frequent cause of overregistering in the use of weirs is the increase in head over the weir above the normal. This may be partially overcome by having all excess water flow over spillways, the longer the spillway the greater approach to normal conditions being obtained. Another method is to keep a continuous record of the flow through the weir notch by means of an automatic register. In still other cases the head is kept constant by means of a gate regulated by a float. Apart from the long spillway perhaps the most effective way of maintaining a constant head over a weir is shown in figure 15, which is a combination of the spillway and valves. By this arrangement valve "b" in the main feed pipe when closed causes the water to rise in one chamber of the box and flow over spillway "a" into the other chamber, while valve "c" is regulated to permit the desired amount of water to flow through the weir "d" into the lateral pipe. It is thus apparent that any slight increase in the depth of water in the spillway "a" will not materially affect the measurement at "d."

Miner's Inch Boxes.

A device of this kind measures the quantity of water which flows through a rectangular orifice under a constant head (fig. 16). The dimensions of the orifice most commonly used in southern California are 4 inches deep and from 2 to 100 inches in length with a head of 4 inches of water over the center of the orifice. The quantity of water flowing through such an orifice is estimated to be 9 gallons per minute for each square inch of orifice or the one-fiftieth part of a cubic foot per second. The Azusa miner's inch box or hydrant shown in figure 17 is fitted with a cast-iron plate which contains four orifices all 4 inches deep and $2\frac{1}{4}$, $3\frac{3}{4}$, $6\frac{1}{4}$, and $12\frac{1}{2}$ inches long, respec-

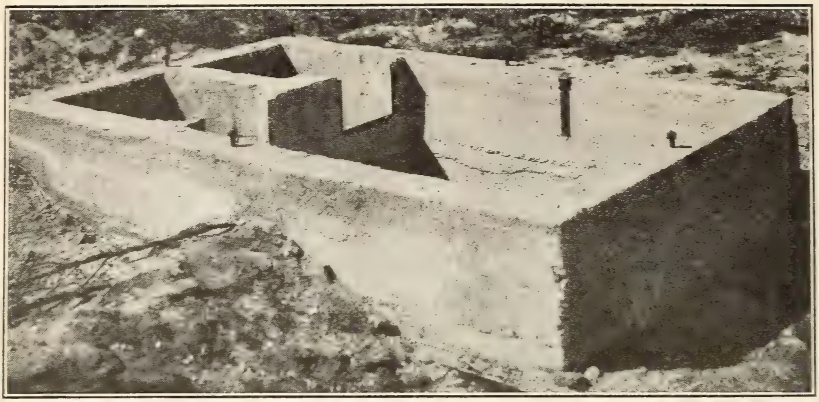

FIG. 12.—Weir box having side contractions too narrow for accurate measurement, athough the discharge over the two weirs may be proportionately accurate.

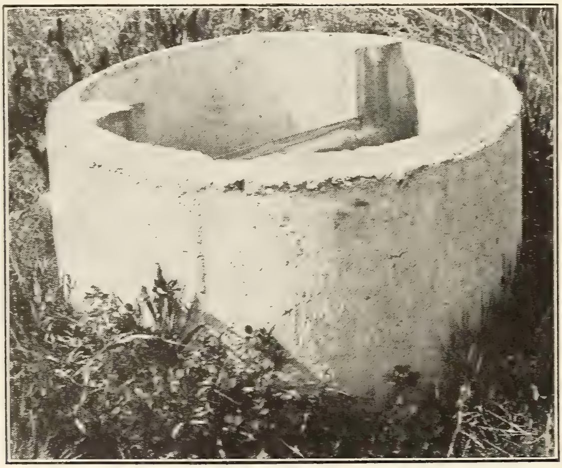

FIG. 13.—Inaccurate weir formed within concrete pipe.

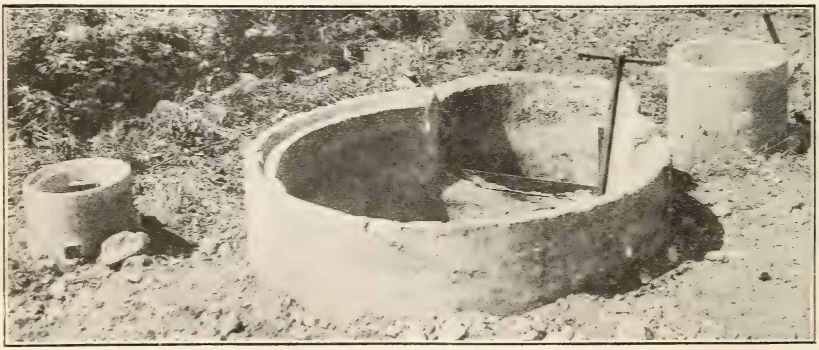

FIG. 14.—Faulty rectangular weir.

tively. Under a 4-inch head over the center of these openings, they will discharge 10, 15, 25, and 50 miner's inches, respectively. When miner's inch boxes are first installed they should be checked against a standard weir in order to test their accuracy. Under constant heads, the miner's inch box measures water with fair accuracy but

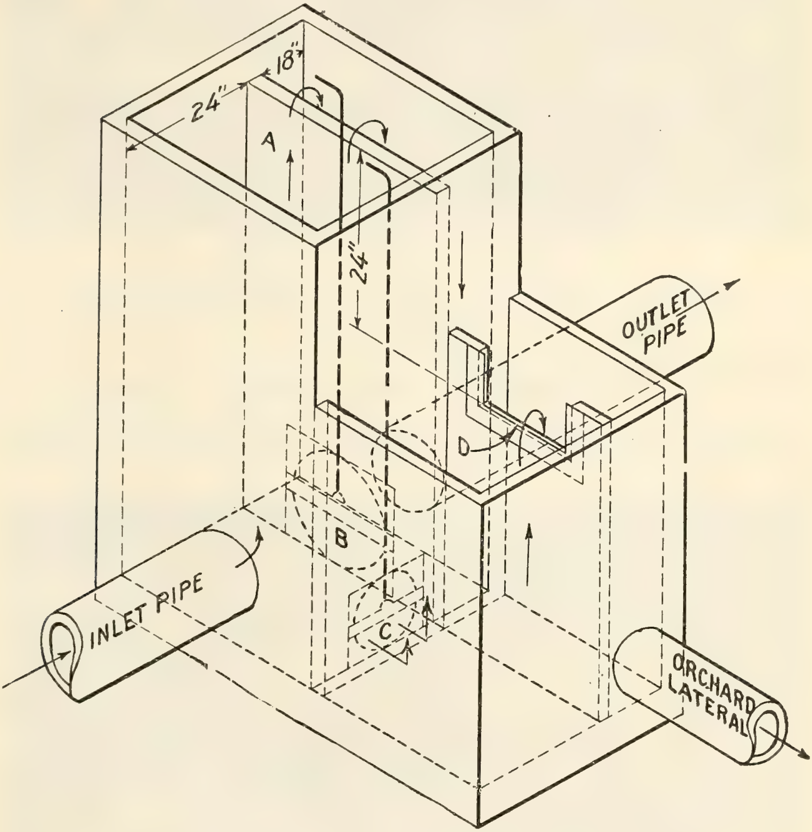

Fig. 15.—Weir box for controlling of head.

where the heads are permitted to vary errors of 100 per cent may be introduced. As in the case of weirs, spillways are used to prevent large fluctuations in heads. One of these is shown in figure 18.

Water registers.

Wherever it is desired to keep a continuous record of the amount of water passing a given point automatic registering devices known as water registers are frequently used. These consist of a drum around which the recording sheet is wrapped and both are attached to a clock which causes them to revolve once in a period of 8 days or more. The record is made on the sheet by a pen or pencil attached to

FIG. 16.—Miner's inch box with waste way.

the rod of a float. The float and its record may measure the height of water over a weir or in a rating channel.

Mechanical recording devices.

These as a rule operate by a vane or propeller revolved by the action of the water as it passes through the meter. They possess an advantage in registering a flow whose record can be readily observed.

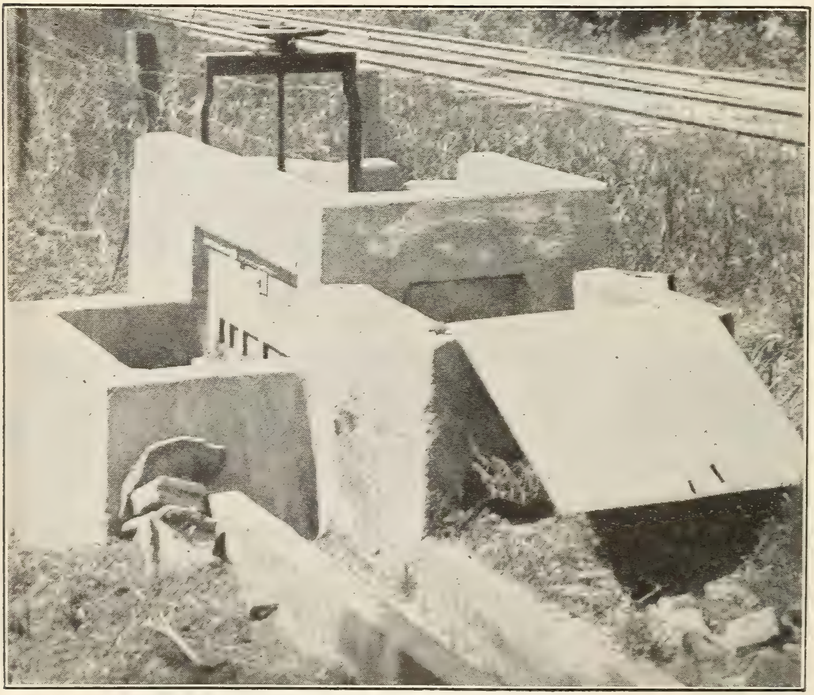

FIG. 17.—An Azusa miner's inch box.

On the other hand, such devices may not measure water accurately particularly in reduced volumes. They are also liable to become clogged with silt, sand, moss, or other débris. Figure 19 shows the exterior of one of these meters.

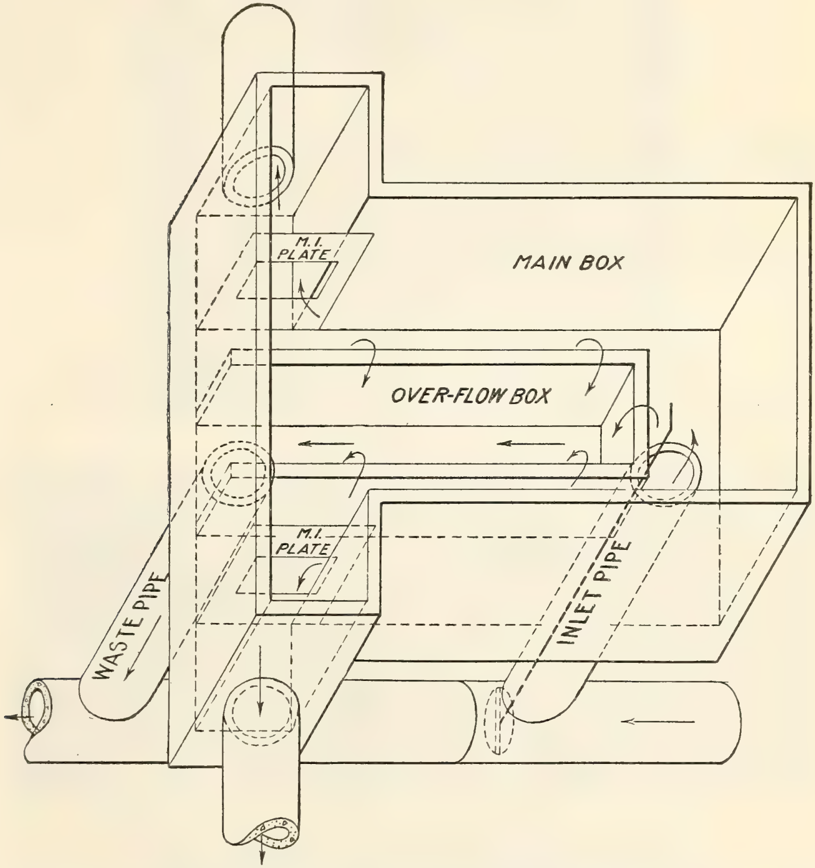

FIG. 18.—Miner's inch box fitted with long waste overflow to minimize change of head through miner's inch plates that feed lateral pipes.

DIVERSION BOXES.

As stated, weirs, miner's inch boxes, and recording devices are usually set in boxes which also act as diversion boxes. Some of the larger rectangular boxes in use have a weir or miner's inch plate on each side and divert water to three or four laterals, as illustrated in figure 20.

It is common practice to measure water at the upper end of a lateral and then install simple diversion boxes at each orchard or farm. These seldom measure water, but are designed so that all

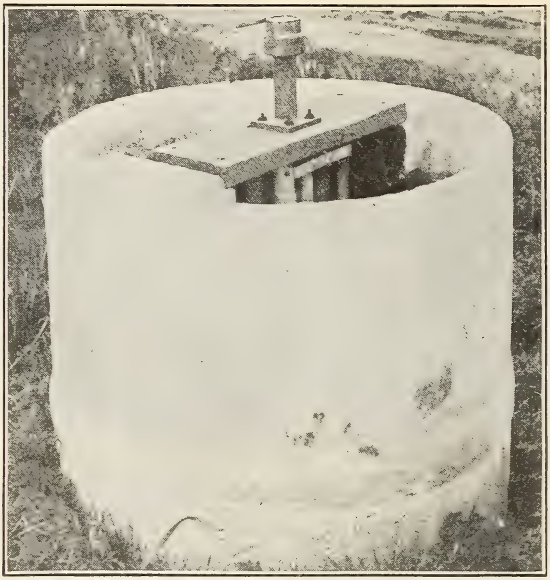

FIG. 19.—Exterior view of recording meter.

FIG. 20.—Diversion box having a weir and two miner's inch plates.

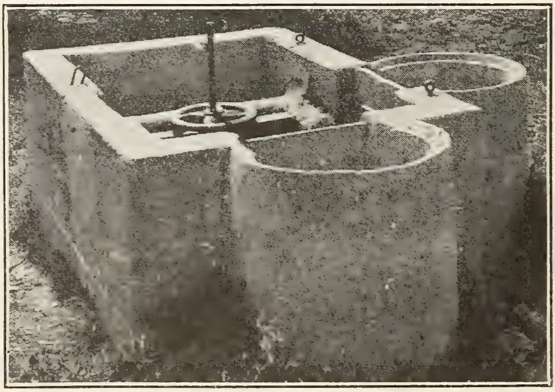

FIG. 21.—A diversion box formed partly of concrete pipe.

the water in the lateral is divided in proportion to the separate acreages to be served. The Covina Water Co. has installed diversion boxes that are fitted with galvanized sheet-iron gates. The gates are all set at the same elevation in the box and water may spill over into the orchard pipe lines on every side of the box. The gates are usually made with rectangular orifices that have several sizes of openings. As the head is the same on each gate, the correct proportion of water will be delivered to each unit, independently of the head over the orifice.

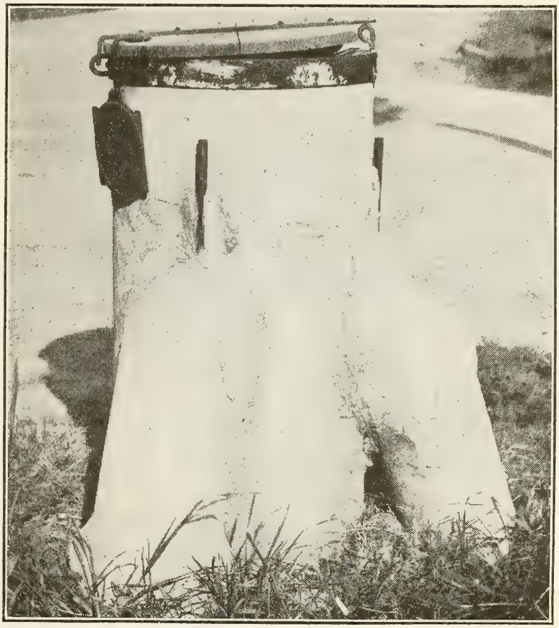

Fig. 22.—A diversion box formed wholly of concrete pipe having small air vents.

Pipe can be used to advantage for constructing diversion boxes as shown in figures 21 and 22. Where there is considerable pressure to contend with at the point of diversion, pipe structures can be built up in a single length to the required height and gates operated from the top of the stands. Overflow stands (fig. 23) can be made by building spillways and thus keeping a constant head on the mains or laterals. Overflow stands may operate automatically, requiring no gates, or gates may be made from ordinary orchard valves that can be manipulated from the outside of the stand.

Where pressure is excessive or there is an objection to high stands, diversion boxes are sometimes built that extend only a few feet above the ground surface, and a top is provided over the stand that will withstand the pressure as shown in figure 24. Alfalfa valves are commonly used to close the top of the stand. Lateral gates may either be of the common, sliding type, or may be orchard valves that are loosened by turning on a threaded bolt.

A diversion box has been designed that will relieve high pressures without the use of high relief or overflow stands. This box makes use of an automatically controlled valve that will open the gate in the main when pressures tend to become high at the point of

FIG. 23.—Overflow stands.

diversion. The valve is controlled by a float in an auxiliary stand. Such an arrangement would have value where high pressure pipe is laid down a steep grade, and where relief stands would have to be excessively high to back water up to all points of diversion. In the above case, water was intended to be used for domestic use and some provision was necessary to keep considerable pressure at each diversion point. It was not practicable to allow the entire head of water on the pipe on account of the steep grades and long length of the main, and relief stands at frequent intervals, high enough to deliver water to the second story of a house were too expensive, and at the same time unsightly.

DISTRIBUTING HYDRANTS.

After water has been conveyed to the field or orchard, the type of distributing hydrant or valve should be selected to suit the soil, grades, and crops to be watered. The most common type of valve consists of a stand of one length of concrete pipe that is fitted with a number of small gates (figs. 25 and 26), the size of the stand and number of gates depending on the number of furrows to be supplied from one

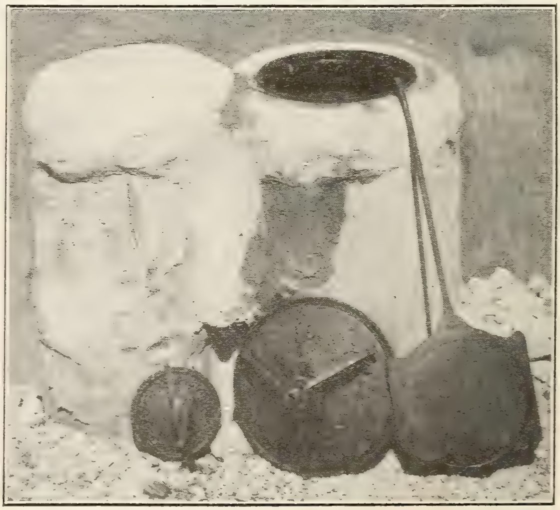

FIG. 24.—A diversion stand with covered top and valves.

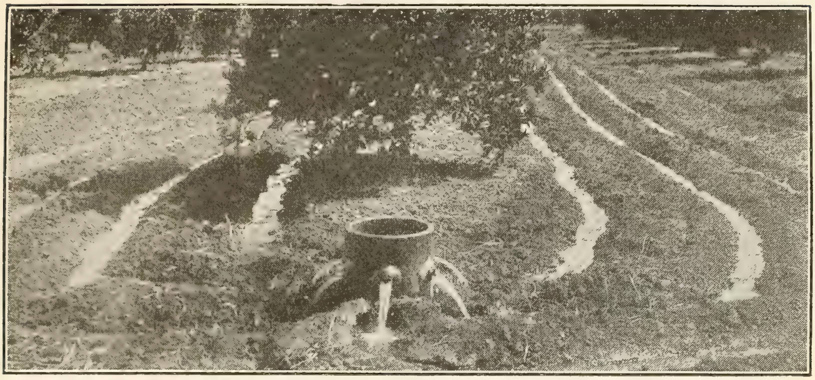

FIG. 25.—A common type of distributing hydrant for orchard irrigation.

valve. The stand is connected to the underground lateral by a short riser and the water is regulated from the lateral to the stand by means of a small valve. A 6-inch concrete pipe stand usually contains two outlets, each from 1 to 2 inches in diameter; an 8-inch stand, 2 to 4 openings; a 12-inch stand, 4 to 8 openings; and a 16-inch stand contains 6 to 8 openings. The concrete risers and stands are usually connected by the pipe contractor when the orchard laterals are laid. The contractor cements the small galvanized gates into the pipe in the yard. A special mold is often used to make the concrete pipe stands, the holes that contain the gates being made when the pipe is in the mold.

FIG. 26.—Distributing hydrants on steep slopes and overflow stands.

FIG. 27.—Distributing hydrant elliptical in form.

Large elliptical, semicircular, or oval stands are used where an extra number of valves are to be connected to one hydrant These special forms (figs. 27 and 28) are also used in sandy soil, where it is desirable to space the spouts as far apart as possible. If several outlets are set in a small diameter pipe, water will wash the furrows together where they connect at the hydrant. Where the larger sized hydrants are used it is a good plan to set them against a curb or fence, otherwise they will be an obstruction to cultivation if placed in the ordinary manner. These large hydrants are sometimes used where the smaller type would answer as well, but they have their use especially in walnut orchards where a large number of furrows are required between tree rows. The oval type set with the long axis parallel to the tree rows presents the least obstruction to cultivation where the stands can not be placed against a fence or curb. There are orchard hydrants which are covered over the top, with no valve connecting stand to the underground lateral, the amount of water delivered to each furrow being regulated by means of small galvanized gates that are attached to spouts set through the sides of the stand. This type is practicable where heads are low, but where pressure is in excess of a few feet the valves are difficult to make water-tight. Leaves and trash also tend to clog this type of hydrant.

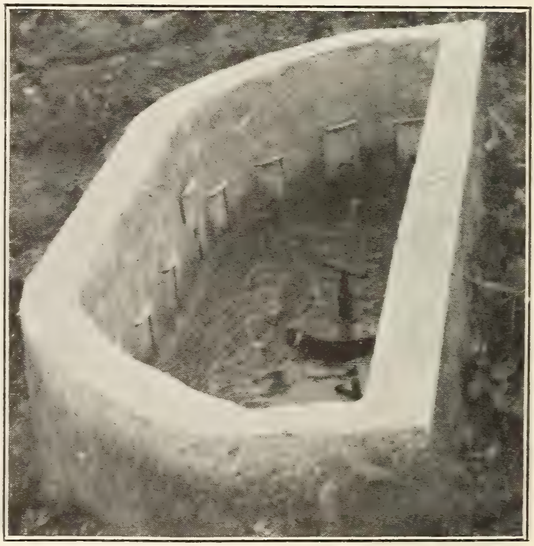

FIG. 28.—Another type of distributing hydrant.

In some cases where it is not desirable to place a number of stands, the hydrants are placed a considerable distance apart, and portable pipes fitted with outlet valves are connected

to the hydrants (fig. 29). This portable pipe is made of light-weight galvanized iron and is easily carried from one hydrant to another. This method assures even distribution to each furrow, and prevents washing at the stand. More labor during irrigation is required, however.

Where hillside land is to be irrigated, several new types of valves have been developed (figs. 30 and 31). Most of these new valves or methods of installation have been developed to assure an even flow from valves in spite of considerable variation in pressure in the orchard lateral. It is common practice in hillside irrigation systems to install the main feed lines along the upper sides of the tracts and to arrange orchard laterals to run down the steepest slope. As some of these laterals run down for several thousand feet on grades that fall from 15 to 35 feet per 100 feet, it can be seen that valves or outlets must be arranged to continually relieve the pressure in the pipe.

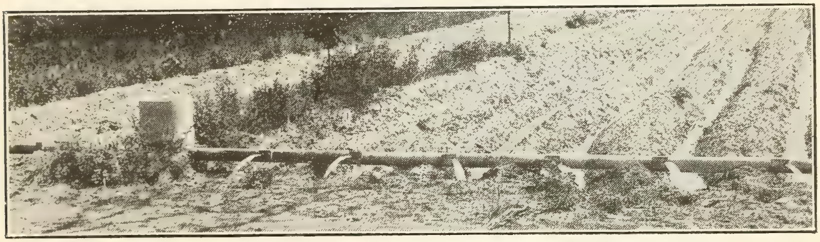

FIG. 29.—Distributing hydrant formed of portable pipe having small sliding gates.

There are several distinct types of distributing systems designed to control pressure. Overflow stands may be placed at stated intervals down grade (fig. 26), the stands being high enough to back water up to the next relief stand above it, distributing hydrants being placed between the relief stands. The relief stand may be made of two parallel concrete pipes set vertically, as shown in figure 32, so that water will rise in one to the required height, and overflow into the other and thence down the pipe to the next stand. The common orchard valve can be used to supply water to the furrows. The stand-pipes may consist of one pipe of small diameter set in another as described in a previous chapter.

The second plan makes use of an ordinary open stand (fig. 33) that does not stand above the ground surface over two or three feet. A pressure gate is cemented to the intake pipe which can be closed and back water up to the next box above. There is no danger of excessive pressures if this plan is followed, providing that stands are not placed too far apart or grades too steep, as water will back up to next stand and overflow it if more water is let into the pipe line than the orchard hydrants will dispose of. The disadvantage of this

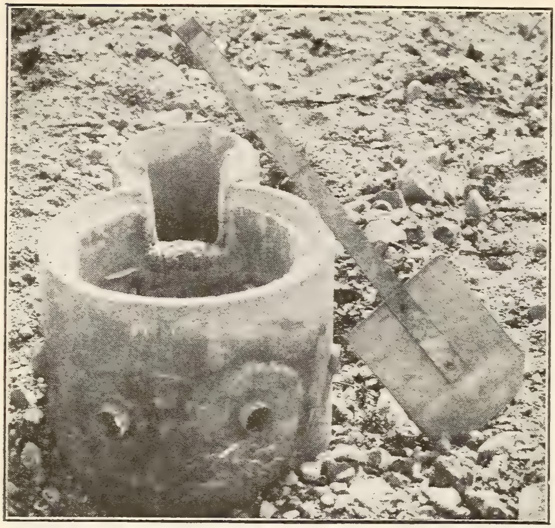

FIG. 30.—A distributing hydrant to reduce water pressure on hillsides.

type is that gates must be regulated very accurately where a large number of orchard hydrants are fed simultaneously. As a rule such construction is best adapted to grades that will allow enough orchard hydrants between two successive stands to take all the water carried by the pipe line.

A third plan that is also adaptable to comparatively small pressures is to provide standpipes at intervals high enough to back water from one to another (fig. 34). The stands may be made of concrete pipe cemented together and set up vertically. A slide gate is cemented to the discharge pipe at each stand, leaving the inlet open. When the gate is closed, water will rise in the stand until it is backed up to the one above it. If an excess of water is turned in the pipe line, these stands will overflow and thus relieve the pressure. This plan is advisable where the gate can be easily manipulated from the top of the stands. If the standpipe is too high, it is possible to install a gate valve or irrigation valve that is boxed in, leaving the handle of the gate to project through a packing box in the top. Some companies have installed a short auxiliary stand immediately below the main standpipe. This stand contains

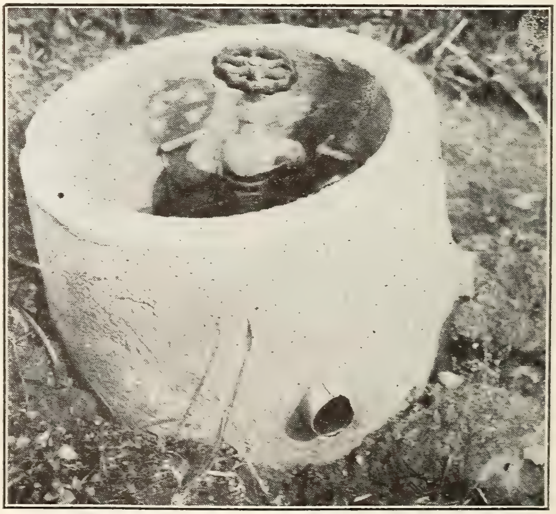

FIG. 31.—Another type of hydrant shown in Fig. 30.

a pressure gate that controls the height of water in the stand. This arrangement is applicable where there is a constant down grade.

Where excessive grades are encountered, it is usual to use overflow distributing hydrants. In this case each hydrant relieves the pres-

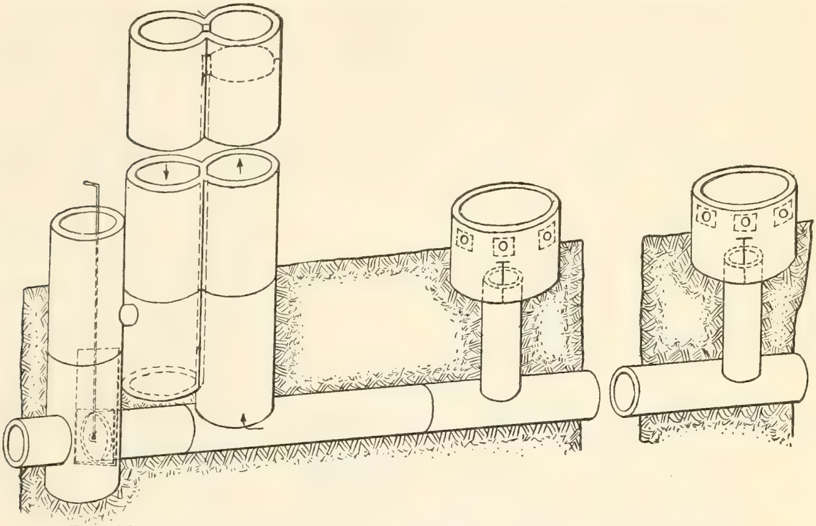

FIG. 32.—Relief stand for preventing excess pressure on concrete pipe.

sure at every tree row. It is not possible to pile up pressures that will exceed the height of the hydrants in this case, irrespective of the grade of the feed pipe. There are three general types of overflow hydrants used and each type may have several modifications

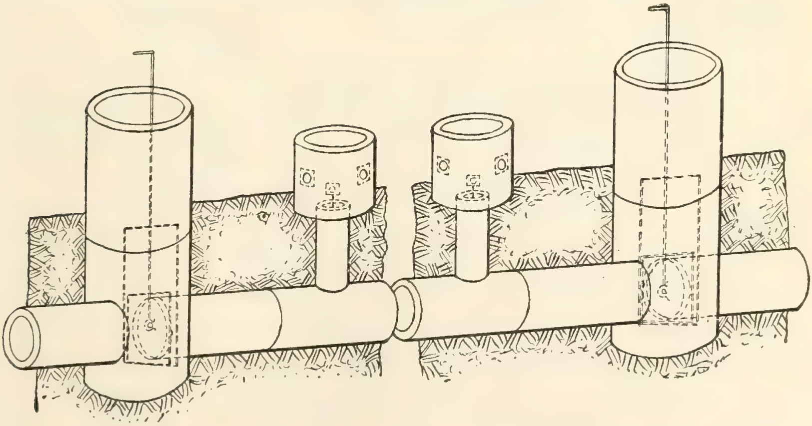

FIG. 33.—Relief of pressure accomplished by short stands with pressure gates.

The most common type consists of two lengths of concrete pipe (fig. 8) set vertically and adjacent to each other. The stand connected to the inlet pipe acts as the distributing hydrant and is fitted

with valves as in the common orchard hydrant. The auxiliary pipe acts as an overflow and is cemented to the outlet pipe, permitting the excess of water to flow down the pipe line to the next hydrant. A small spillway connects the two stands, the spillway being set high enough to allow a few inches head on the gates set in the upper stand (fig. 10). A modification of this hydrant is fitted with lift gates, so that all the water may flow down the pipe line and not be forced to spill over the wasteway of each valve. Others have no gates, all the water being forced to rise in each stand and overflow into the pipe line. Where the valves are set on a long lateral that runs down on a steep grade, it is usually necessary to provide gates in the pipe line so water can flow unobstructed to any set of valves.

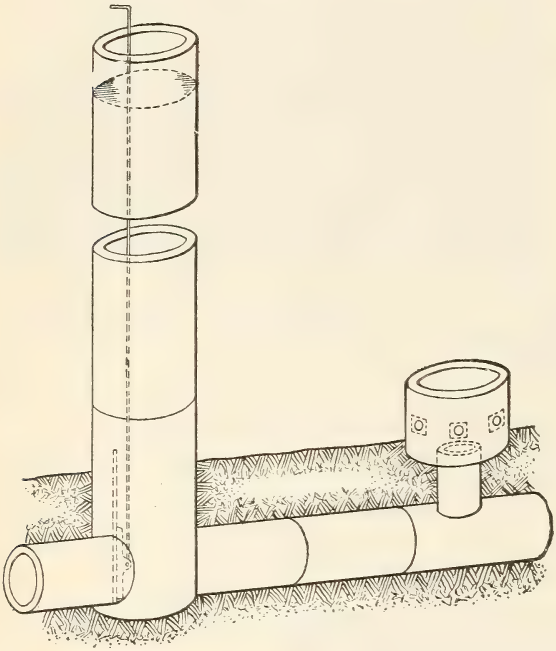

FIG. 34.—Plain relief stand. Standpipe is high enough to insure pressure on field hydrants above it. Excess pressures on pipe line impossible, as standpipe will overflow when all orchard valves above are closed.

Another type of overflow hydrant is constructed by placing a partition wall in a single length of pipe. The water is forced over the partition wall when operating and spills over into the outlet to the next valve. Small outlet gates that feed the furrows are set in the inlet chamber, the presssure on the gates depending upon the height of spillway above them.

The third type is made of one large stand, consisting of one joint of concrete pipe having a pipe of smaller diameter set inside. The small pipe acts as the spillway and is connected to the outlet pipe.

When these valves are constructed properly they are nearly ideal for irrigating side-hill orchards, where only a small stream is required to each furrow. They are well adapted to contour and terrace plan of irrigation.

The greatest difficulty with overflow relief standpipes and overflow orchard hydrants is the trouble caused by entrapped air. If the sheet of water flowing into the outlet stand entirely covers the opening into the underground pipe air is carried down with the sheet of water and is not able to escape, due to the aperture being closed with water. In many cases more than three or four overflow hydrants can not be operated at one time, due to air trouble. If the hydrants or relief stands are fitted with gates at the connection to the feed pipe and the valve opening is large enough to take the full head of water, there will be little trouble with air. Such valves are sometimes difficult to adjust, however, especially where a portion of water is to be distributed through the hydrant.

The way to prevent air troubles in this type of orchard hydrant is to construct the outlet from the spillway large enough so that the entire space will not be filled with water at any time. If there is a clear space above the outlet feed pipe and the aperture from valve to feed pipe is never entirely covered with water, air will be able to escape.

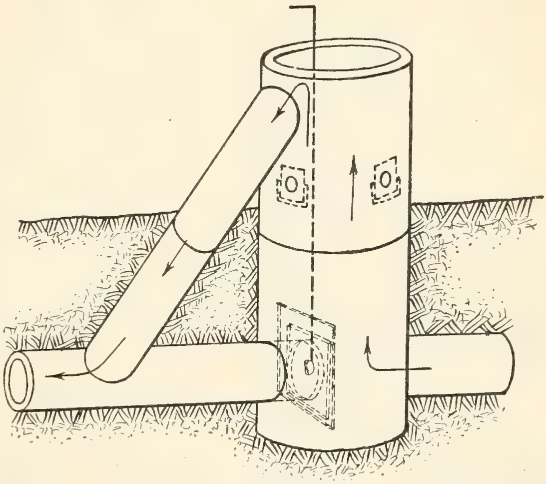

FIG. 35.—Overflow distributing hydrant. Wasteway pipe set on angle to prevent air troubles.

The spillway pipe can also be set at an angle so that water wasting into the outlet pipe will never entirely fill it (fig. 35). If the spillway pipe is of small diameter and set inside a large diameter pipe it is necessary to have the outside pipe very much larger than the spillway pipe. The Lemon Heights Land Company near San Diego has a large number of overflow stands that are made by using the main hydrant of 20-inch pipe and the spillway of 4-inch pipe. The spillway pipe was originally set vertically, but there was so much trouble from air that all stands were changed by setting the spillway at an angle of about 45 degrees with the vertical. A notch was cut in top of the spillway pipe so that water would flow through it without entirely filling it. There has been no trouble from air since the

change in design. This valve is provided with a lift gate in the bottom so that some of the water can flow to the lower hydrants without having to be forced through each valve. A much smaller pipe could be used for the main distributing hydrant if the spillway pipe was set through the lower side of the hydrant, and set on an angle to the underground pipe. Smaller spillways could also be used if this plan was followed, without danger from entrapped air.

Where sandy soil is to be irrigated, and furrows run on a gradual grade it is often best to do away with the ordinary stand that extends above the ground. An orchard valve or alfalfa valve can be cemented to the riser, having the riser cut off 4 inches to 6 inches below the ground surface. If the valve is set inside the first tree and in every tree row it will be no obstruction to cultivation. Where sandy soil is encountered it is often impracticable to attempt to run a number of furrows between the rows on account of the rapid percolation of water into the subsoil. It is a common sight to see sandy ground watered by using the ordinary hydrant fitted with 4 to 6 outlet gates, and either allowing all the gates to spill in one main furrow or letting the water run over the top of the stand. Where flooding or basin irrigation is practiced there is no need of a number of small outlet valves set in one hydrant.

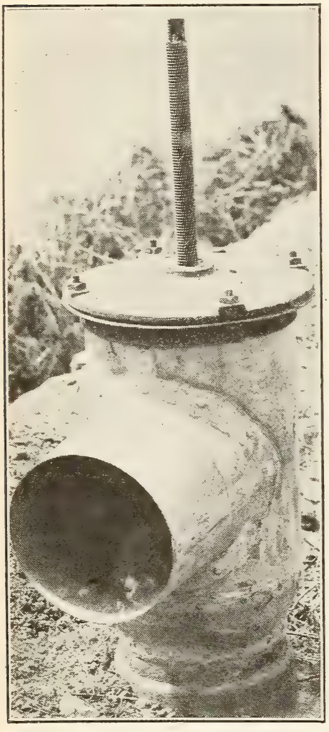

FIG. 36.—Distributing hydrant for large irrigation heads, such as are used in irrigating alfalfa.

Where flooding is resorted to for alfalfa or orchards having very flat grades and sandy soil, risers are set at convenient intervals that are capped with a special lid. This cap can be removed and a portable hood or hydrant attached to it (fig. 36). There are a number of different types on the market. The best portable hydrant can be fastened to the riser before the cap on the riser is removed or loosened. Portable pipe made from light-weight galvanized iron can also be easily attached to these portable hoods. This arrangement is often used where alfalfa is irrigated, but may be used to advantage in orchards where soil or grades will not permit of furrows.

Where steel pipe is used for distributing water, the outlet valves are usually the common hydrants or faucets used in domestic water

supplies. They may be connected to concrete stands fitted with small gates or flumes and galvanized pots fitted with spouts may be used to feed the furrows. Some orchardists have utilized short lengths of standard three-quarter-inch steel pipe to distribute water to the furrows. Water is distributed through small holes bored in the pipe, each hole feeding one furrow. In the latter case a connection is made to the iron pressure pipe at every tree row. The distributing pipes are about 8 feet long, and are fitted to the riser by pipe fittings so that the pipe may be let down on the ground when irrigating, or set up vertically out of the way of cultivation.

As regards irrigation gates and valves, it is a safe plan to install makes that have all threaded or sliding parts either of brass, bronze, or other composition metal that will resist rust. Gates whose wearing parts are cast iron throughout are liable to corrode and stick. Cast iron, however, is satisfactory for parts that do not wear, or for seats to make a water-tight connection. Most gates are constructed to work with the water pressure, the pressure tending to make them more water-tight. There are a number of pressure gates manufactured that are held against the pressure by being clamped tightly against the frame. Most gates are not built for heads over 15 to 25 feet. Special gates can be ordered for higher pressures. It is better, however, to construct boxes so that pressures will tend to hold gates in place whenever possible.

An average price for pressure gates including frames was about as follows July, 1919:

6-inch	$5. 75
8-inch	8. 00
10-inch	10. 00
12-inch	16. 00
16-inch	28. 00
18-inch	36. 00

These gates are fitted with a locking device that will hold the gate in any position, and are used both against and with pressure. Plain gates without the locking device sell for one-half to one-third of the above price.

Orchard valves for controlling water from pipe line to hydrant stand sell for about as follows:

6-inch	$1. 25
8-inch	1. 50
12-inch	4. 00

Alfalfa valves without hoods cost about $4.50 for 6-inch size; $6.75 for 10-inch, and $9 for 12-inch. Portable hoods or hydrants for flooding or for use with light-weight portable galvanized-iron pipe cost about $12.50 for 6-inch hydrant and $18 for 12-inch size.

One pipe contractor in southern California quotes the following prices for standard orchard stands installed in the field fitted with $1\frac{1}{2}$ inch galvanized gates:

8-inch stands, 4 openings	$2.25
12-inch stands, 4 openings	2.50
12-inch stands, 6 openings	2.70

Another contractor quotes the following:

12-inch stands, with 4-hole openings	$3.50
12-inch stands, with 6-hole openings	3.75
18-inch oval stands, with 6-hole openings	4.00
18-inch oval stands, with 8-hole openings	4.25

It should be borne in mind that the large majority of concrete pipe systems under operation are made of pipe of medium if not inferior grades and that the relief stands, diversion boxes, and other appliances designed to relieve water pressures have been adapted to this kind of pipe. With the introduction of a better grade of pipe capable of withstanding higher pressures the necessity will arise of modifying the present practice by using more high pressure valves and fewer standpipes, and this change should lessen the cost of pipe systems. In other words, if concrete pipe in the smaller sizes can be made to withstand with safety heads of 50 feet, it should tend to revolutionize the present costly system of reducing the pressure to 10-foot heads, particularly on steep slopes.

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